

East/Central Contra Costa County Wastewater
Management Plan: Acute Impact of Discharge at
Alternative Outfall Locations

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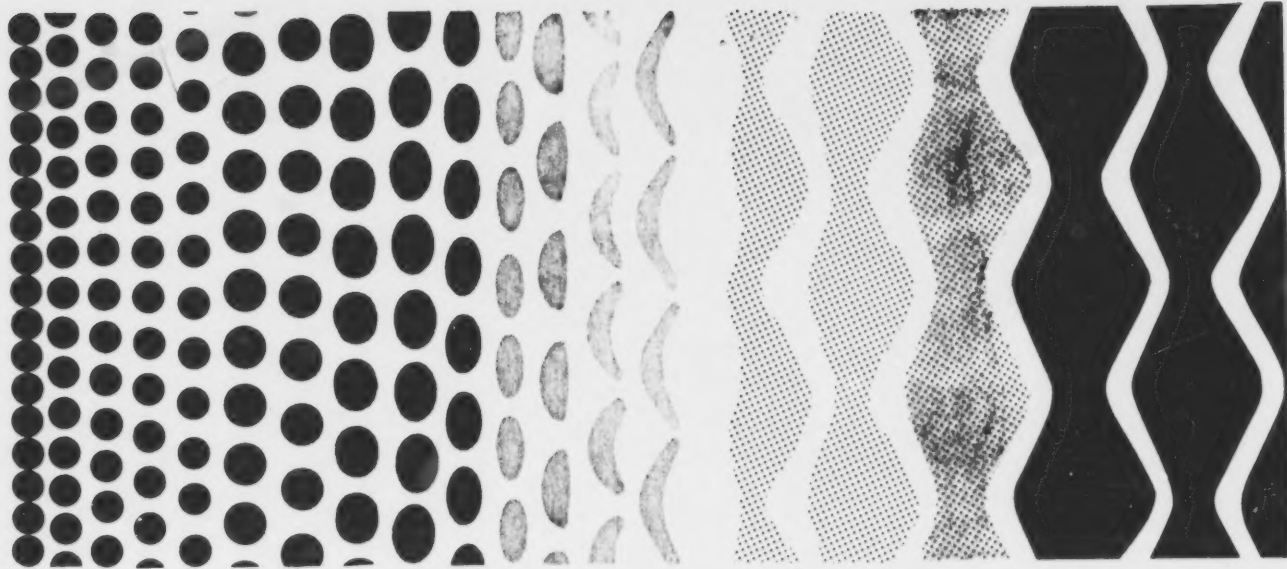
EAST / CENTRAL CONTRA COSTA COUNTY WASTEWATER MANAGEMENT PLAN

**Acute Impact of Discharge at
Alternative Outfall Locations**

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June 1976



EAST/CENTRAL CONTRA COSTA COUNTY WASTEWATER MANAGEMENT PLAN

JUNE 1976

NOTE:
This discharge alternative analysis and comparison refers to the project described in the Draft EIR/EIS for the East/Central Contra Costa County Wastewater Management Program. Please refer to the May 11, 1976 transmittal letter that accompanied the Draft EIR/EIS.

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PREFACE

The East/Central Contra Costa County Wastewater Management Program is a comprehensive review of wastewater service for some 90,000 persons in Contra Costa County, California. In order to adequately treat the area's municipal wastewater and protect the quality of receiving waters from undesirable levels of pollutant discharge, the Management Program entails improvement to sewage plants within the Agency jurisdiction.

A Draft Environmental Impact Report & Statement (EIR/EIS) was prepared for the wastewater management plan (April 1976).

The proposed project described in the Draft EIS/ Central Contra Costa County Wastewater Management Agency) after evaluation of preliminary data from the engineering and EIS/EIR consultants. However, a review by EPA and other regulatory agencies indicated that two additional discharge locations should be considered for the treatment facility to service the industrial shore area (Shore Acres, Pittsburg, Antioch). These locations include points along the Sacramento River north of Brown's Island and at Shore Acres, in addition to the proposed discharge to New York Slough.

The present study is an analysis and comparison of the acute, local impacts of the three alternative discharge locations. The scope of the study was determined by the U.S. Environmental Protection Agency and several review agencies which included the U.S. Fish and Wildlife Service, the State Department of Fish and Game, the State Water Resources Control Board, the Central Valley Regional Water Quality Control Board, and the San Francisco Bay Regional Water Quality Control Board. The purpose of the study was to examine the acute, short-term impacts on finfish in the immediate vicinity of the discharge point. The study was not intended as a regional assessment or for engineering design.

SUMMARY AND CONCLUSIONS

[This study is an analysis and comparison of three alternative discharge locations for the North Shore sub-regional wastewater treatment facility. It is intended to address only the acute, local impacts on fish that result from immediate effluent dilution in the vicinity of the outfall.]

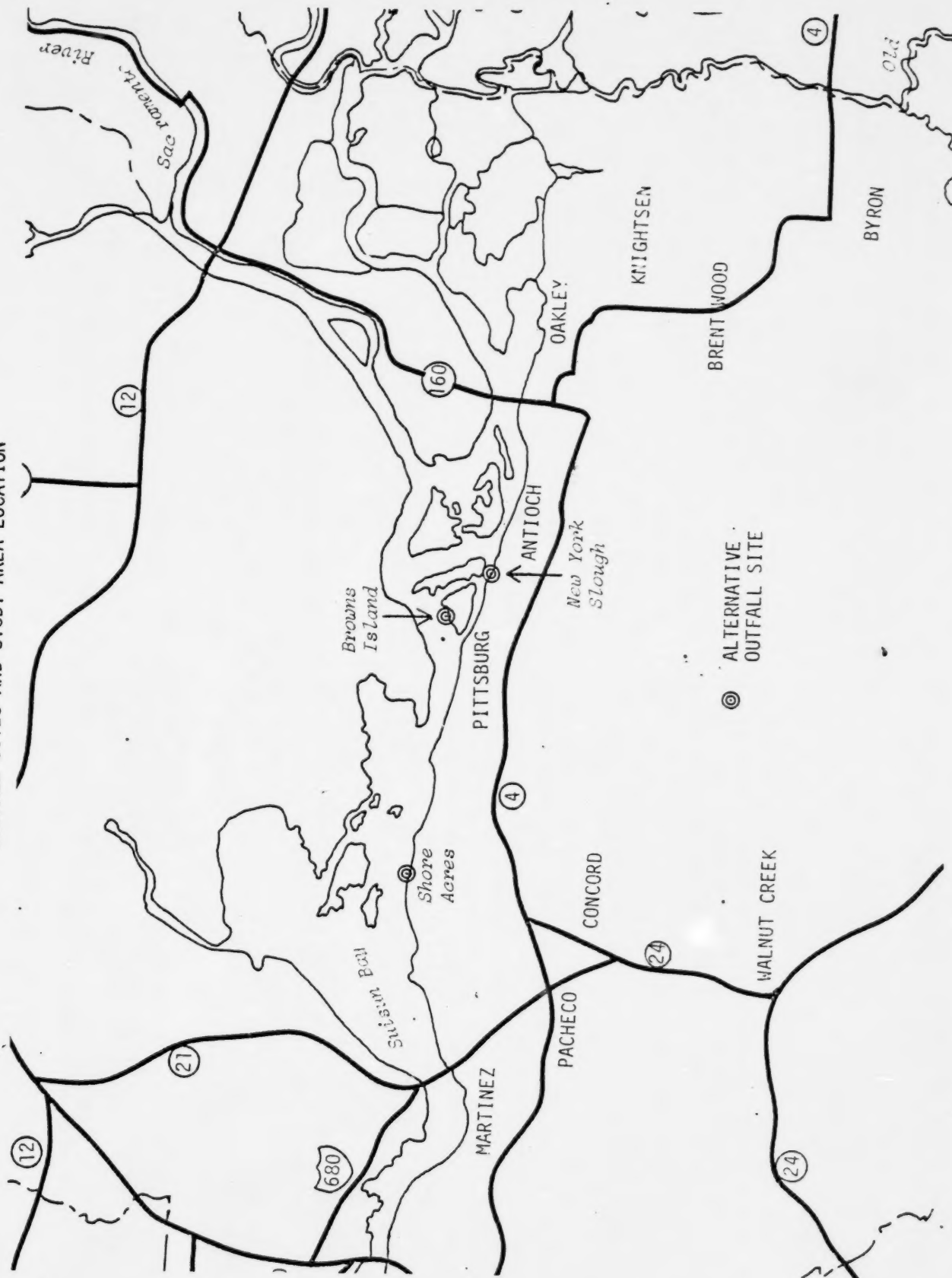
Alternative Wastewater Discharge Sites: [Three alternative sites are located 45 to 55 miles upstream in the San Francisco Bay estuary in an area dominated by tidal flow. There is variable salinity and semi-diurnal tidal change resulting in alternating upstream and downstream currents which alternate every 6 1/4 hours.]

The proposed discharge into New York Slough is closest to the proposed subregional facility between Pittsburg and Antioch. New York Slough is a narrow but deep channel cut between the San Joaquin and Sacramento rivers. It carries approximately 40% of the flow from the San Joaquin Rivers; current is strong and uniform throughout the cross section of the channel. New York Slough is used for shipping and the diffuser must be oriented parallel to the current which reduces its effectiveness.

The Browns Island alternative discharges into the main channel of the Sacramento River north of Browns Island. This outfall would also serve the Pittsburg/Antioch subregional facility, although it would require 9000 feet of additional outfall pipeline. The volume of tidal flow as well as fresh water flow through the main channel opposite Browns Island is three times greater than the flow in New York Slough. The large cross-section, however, results in currents equal to New York Slough. These are uniformly distributed in the vicinity of the outfall, where the diffuser may be oriented perpendicular to the current.

The Shore Acres alternative discharges into the Sacramento 10 miles further downstream. This would

OUTFALL SITES AND STUDY AREA LOCATION



require relocation of the subregional facilities to Shore Acres. The outfall is presently located on a side channel of the Sacramento, resulting in currents less than those experienced at the other two locations. The net volume of water at Shore Acres is greater since it represents the total combined tidal prism and fresh water flow of the Sacramento and San Joaquin Rivers. The diffuser may be located perpendicular to the river current.

[The wastewater from the subregional treatment facility on the North Shore of Contra Costa County will be discharged through a submerged outfall.] Preliminary design indicates that the diffuser will be 200 feet in length lying at a depth of 20 feet below mean low water. For the purposes of alternative comparison, the same diffuser design is assumed for each location. Narrow discharge ports will create a high velocity jet of effluent. Turbulence between the discharge and the surrounding water will result in rapid initial mixing. In addition to the momentum from discharge, the effluent is expected to be slightly less dense than the surrounding fluid due to low total dissolved solids (TDS) and elevated temperature (5-10°F). In theory, the diffuser at each of the three sites should create a line source discharge with initial dilution at the surface of 45:1 minimum and 60:1 average.

[With continuous discharge and very low current, the supply of clean water for dilution becomes limiting.] Currents below 0.1 knot (10 feet/minute) allow a cloud or pall of diluted wastewater to form above the outfall site. This current value, designated as the "critical current," defines a period of time during the changing of the tides when the pall will be formed. For weak tides (occurring 10% of the time), the duration of the pall formation is on the order of one or two hours depending on the location. This effect gradually reduces dilution in the vicinity of the diffuser, resulting in approximately 20:1 dilution over the diffuser and 35:1 dilution in the majority of the pall itself.

With high river current the pall does not form and the effluent is rapidly diluted forming a thin plume trailing downstream. With the current above the "critical" level, dilution of 40:1 or better is achieved within 100 feet of the outfall.

Initial dilution may be increased by engineering design modification. If it is deemed desirable, changes in flow rate by storage and pumping, or changes in port size or diffuser length may be incorporated in Stage II Facility Design in order to increase initial dilution.

Pollutants: High, short-term concentrations of wastewater pollutants may cause acute adverse impacts on fish. Although the project has little industrial waste and will meet current permits, several of the components of domestic wastewater were selected by the regulatory agencies for study.

Biological oxygen demanding material (BOD) may cause dissolved oxygen depression suffocating aquatic life.

Heavy metals can cause acute toxicity at high levels or cause avoidance behavior in migratory fish at low levels.

Chlorine residual from effluent disinfection is highly toxic to aquatic life.

Ammonia from the waste stream is toxic, particularly in alkaline waters.

Receiving water biota--finfish: Many fish species use the Sacramento/San Joaquin Delta. Those most sensitive to pollutants and those most valued for recreational fishery are the introduced game fish (striped bass) and native Salmonids (salmon, trout).

These anadromous or migratory fish are subject to interference as adults if high pollutant concentrations block migratory channels. They are also affected if pollutants reach levels sufficient to injure the most sensitive larval stages or to kill the principal food source for the fish, the Opossum shrimp, *Neomysis*.

The Sacramento main channel is most heavily used by all fish species. The San Joaquin and New York Slough, however, are important for bass.

Project effluent under normal operating conditions is tolerated by sensitive species for periods of a few hours if dilution is greater than 40:1. Under conditions of plant failure or dechlorination, malfunction, residual chlorine or ammonia may be toxic, requiring dilution of 100:1 or better to prevent acute mortality to sensitive species such as trout, salmon.

IMPACT OF DISCHARGE ALTERNATIVES

The worst case is peak discharge during slack water after a weak tide. The worst case is expected to occur 10 times per year and will last for roughly three hours. During this period a pall of partially diluted wastewater forms in the vicinity of the outfall site. As tidal current increases after slack, the pall is moved away from the outfall and carried along the river, expanding and diluting through turbulence within the channel. Variations in net fresh water outflow due to seasonal variation or Delta withdrawal have little effect on the size or dilution of the pall; rather they affect its timing in relation to the tidal cycle.

The average case is average discharge, and average tidal flow. These conditions will be exceeded one half of the time. The fate of discharge is similar to the worst case, but dilution is better and duration of exposure is less.

Consideration of current cycle, discharge characteristics and hydraulic environment at each site allow estimates of the relative dilution achieved at each site.

The alternative discharge sites do have slightly different hydraulic environments, and impact will vary between alternatives. The difference is small, however, and should be regarded only as an indication of alternative preference that may be weighed against other factors. In particular, the reader is cautioned that dilution calculations in a shallow tidal estuary are only approximate, and that the differences observed between the three alternatives is within the probable error of this method.

AVERAGE VS WORST CASE PALL

PARAMETER	NEW YORK SLOUGH	BROWNS ISLAND	SHORE ACRES
Time of Formation (min)	55 15	55 15	120 35
Pall at end of Slack			
Width (ft)	520 300	750 450	780 575
Length (ft)	950 500	720 350	980 450
Average Dilution	20:1 41:1	23:1 48:1	22:1 45:1
Time Required to Reach 100:1 (hrs)	4 2	4 2	4 2

Bold Face = Worst Case; Weak Tide Discharge
ITALIC = Average Case

DILUTION WITH CURRENT

TIME AFTER CURRENT REVERSAL (min)	INITIAL DILUTION		
	NEW YORK SLOUGH	BROWNS ISLAND	SHORE ACRES
15	*23:1 47:1	*27:1 48:1	*27:1 48:1
30	*20:1 41:1	*24:1 75:1	*24:1 45:1
60	24:1 58:1	48:1 145:1	*23:1 96:1
120	30:1 76:1	84:1 250:1	56:1 170:1
180 (peak current)	30:1 90:1	100:1 300:1	67:1 200:1

Bold Face = Worst Case; Weak Tide Discharge

ITALIC = Average Case

* Denotes Average Dilution with Pall

Considering first the project as a whole, the foregoing analysis shows that the receiving waters of the Study Area generally provide a sufficient hydraulic environment for effective wastewater discharge dilution.

With normal plant operation, even worst case outfall conditions result in clearly tolerable concentrations (40:1 dilution) within less than two hours. Under average conditions, tolerable levels are achieved very quickly.

In the event of catastrophic treatment plant failure, unrestricted peak flow discharge under worst case conditions would result in

high residual chlorine that could persist at unacceptable levels (less than 250:1 dilution) for as long as 8 hours. That event would cause mortality to sensitive species such as trout and *Neomysis*, and possibly to bass. Under average conditions, the exposure to unacceptable levels is reduced to roughly one hour or less; and the magnitude of potential fish kills would be less.

Among the three alternatives, New York Slough is least effective in diluting project effluent. Slightly smaller dilutions are obtained under both worst case and average current conditions. The principal factor that determines this result is the orientation of the diffuser parallel to current flow, due to the New York Slough ship channel. If the outfall were oriented perpendicular, the dilution at New York Slough would be nearly identical to the dilution at Browns Island.

Since the channel at New York Slough is narrower than at the other locations, there is greater potential for channel blockage. Under normal operation, no adverse effect is expected due to channel blockage. The general chlorine toxicity resulting from catastrophic plant failure would largely block the channel if it occurred during ebb tide. Although more sensitive species make primary use of just the Sacramento System, New York Slough is an important migrating route to the Delta for bass.

The discharge at Browns Island will have slightly better dilution under all conditions than either alternative and lies in a broad channel less subject to blockage by the waste plume under conditions of plant failure. On flood tide, the pall of waste

will probably be carried into the San Joaquin; on ebb, the pail will remain in the main channel of the Sacramento, and may interfere with important migratory routes.

Since Shore Acres discharges into a side channel, conditions result in longer periods of waste accumulation, and dilution is intermediate between the other two discharge alternatives. On flood tide, the side channel will be blocked under most conditions although this should not affect major fish movements.

Possible Modification and Mitigation

The slightly greater dilution of the alternative sites and the reduced impact of chlorine toxicity during plant malfunction suggest that relocation of the outfall site from New York Slough would reduce the acute, local water quality impact of surface discharge. However, since dilution is a function of outfall design as well as hydraulic environment, it is possible to devise modifications in design that can compensate for any differences. If the impact at New York Slough were considered undesirable as proposed, design modification may be as effective as outfall relocation in mitigation.

Two possible modifications would be effective:

- 1) Orient diffuser perpendicular to current, away from ship channel.
- 2) Provide substantial detention capacity to control discharge in relation to tidal stage or in the event of dechlorination failure.

The additional cost for these modifications is not trivial, yet is far less than the anticipated cost of re-locating the outfall site to Browns Island or to Shore Acres. The results of the acute impact analysis do not indicate whether or not the difference in dilution observed for New York Slough is unacceptable.

able; that is a matter for the review and decision making process. Design modification becomes important only if it is determined that some mitigation is necessary and if a cost effective alternative to outfall relocation is sought.

INTRODUCTION

Present technology relies on the use of water as a cleansing and waste removal agent for homes, business and industry. The wastewater generated by man's use must be disposed of in some fashion, and traditionally, disposal of wastewater in rivers, lakes or oceans has been seen as the simplest and most cost-effective manner of disposal. Despite alternatives such as land disposal or reclamation and reuse of treated wastewater, wastewater discharge to surface waters still constitutes the most common disposal technique. The use of receiving waters for waste disposal, however, is limited by interference with other uses which require clean water. Such beneficial uses as water supply, fisheries, recreation, and generally the overall sense of environmental quality in a community's surroundings are all subject to serious degradation by pollution.

In order to minimize the conflict between wastewater disposal and other uses of the receiving waters, sewage is collected for treatment to reduce its pollutant burden. The treated wastewater is then discharged through an engineered outfall which is designed to rapidly dilute the wastes in the surrounding waters and which is located in areas of minimal biological sensitivity and high intrinsic waste assimilative capacity.

The treatment proposed for the north shore communities of the East/Central Contra Costa Waste-water Management program is secondary treatment, reducing suspended solids and biological oxygen demand, with chlorination for disinfection and subsequent dechlorination to remove the chlorine residual. By 1996 an average of 12.4 million gallons per day (MGD) of effluent would be discharged to the surface waters of the Sacramento-San Joaquin River System.

The purpose of this study is to identify and compare the acute short-term and local impacts of wastewater dis-

posal at three alternative locations along the study area. The impacts will be considered primarily in relation to receiving water biota, specifically, finfish. To do this the study first examines the wastewater disposal process and outlines the factors which determine the degree and rapidity of wastewater dilution by the receiving waters. Second, the study describes the proposed outfall site on New York Slough and the two alternative sites located on the Sacramento at Browns Island and the Shore Acres. Third, the study enumerates the pollutants of concern; in this case they are the heavy metals, toxicity from residual chlorine and ammonia, and the biological oxygen demand (BOD) with concomitant dissolved oxygen (DO) depression. Fourth, the study characterizes the receiving water biota and describes their sensitivity to disturbance from water quality changes. Lastly, the projected waste loads and dilutions are compared with the characteristics of the outfall sites and fish species to forecast the environmental impact of waste disposal in these three locations.

WASTEWATER DISPOSAL BY SURFACE WATER DISCHARGE

INTRODUCTION

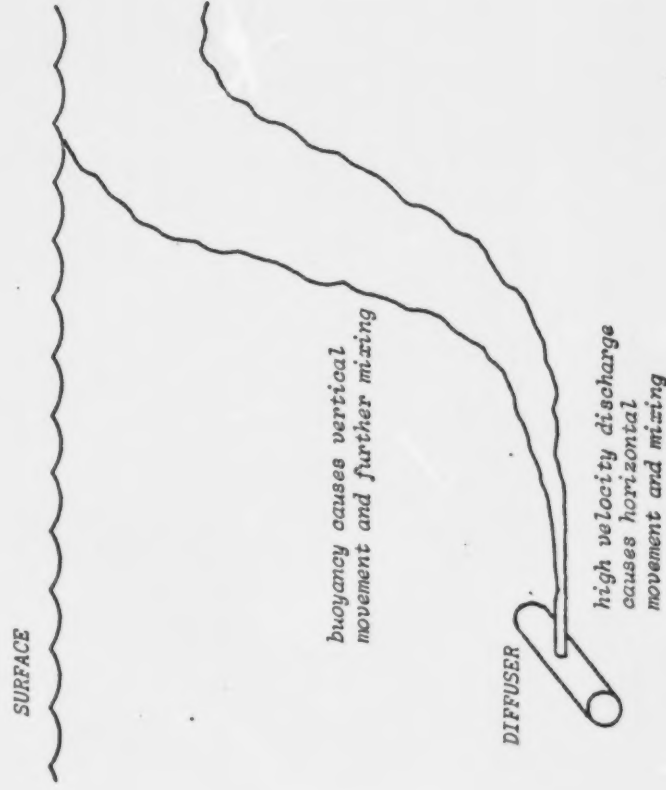
This method of wastewater disposal relies on dilution of pollutants by the receiving waters. At some point the concentration of waste becomes sufficiently low that the pollutant is considered dispersed and has been disposed of. Some pollutants such as DDT which do not degrade rapidly in the environment can accumulate in harmful quantities even after dispersion, and the philosophy of disposal by dilution does not apply. Dilution is a valid technique for disposing of the pollutants under consideration, since they do not accumulate in the environment. They either decompose over time, become immobilized in sediments, or are already naturally occurring in the aquatic environment. Although long-term effects may be important, this study is limited to the immediate process of dispersal.

Dilution of wastewater effluent occurs in four stages. Initial dilution is achieved through turbulent mixing of the effluent jet discharged from the outfall diffuser. Further dispersion occurs when the partially diluted waste stream forms a cloud or pall above the outfall. If there is any current in the vicinity of the outfall the pall of waste will be slowly shifted downstream. With continuous discharge this gives rise to a plume with the diffuser at its head and which trails out in the direction of the ambient current. Further dilution occurs as the plume travels away from the source. Ultimately, the waste becomes well mixed within a segment of the river and no appreciable zones of high concentration are noted over short distances. Nonetheless this slug of waste must travel up and down stream with successive tides, gradually becoming more and more dilute and ultimately being discharged into the Pacific Ocean. The fate of the pollutants after discharge into the ocean is not considered here.

JET

The jet is fundamental to diffuser action. In it, there is rapid mixing of effluent due to the movement of the discharge stream through ambient waters. This relative movement or momentum of the waste stream is due to 1) the initial momentum obtained upon high velocity discharge through the diffuser ports, and to 2) momentum gained from buoyancy and the tendency of waste-water to rise in the surrounding fluid if it is less dense. See Figure 2-1.

Figure 2-1 JET



The discharge velocity is subject to engineering determination. Typical outfall design comprises a pipeline from the shore terminating in a section called the diffuser. The diffuser in this case will be 200 feet in length and perforated with holes approximately four inches in diameter, spaced ten feet apart alternately on either side. With wastewater flows on the order of 12.4 mgd as expected for this project, this outfall is designed to achieve a jet velocity of ten feet per second and achieve an initial dilution in 20 feet of water of better than ten to one at the surface. (Project report appendix A). In fact, as will be demonstrated later, the dilution expected under most conditions will be better than twenty-five to one for this diffuser.

The dilution factor used in this and other studies to describe wastewater disposal refers to the volume of receiving water that has become mixed with a unit volume of wastewater. Dilution factors allow ready calculation of pollutant concentrations. For example, if the waste stream carries a pollutant load of 100 milligrams per liter (100 mg/l or 100 ppm), then twenty to one dilution (20:1) would mean that the pollutant burden would have been mixed with twenty times the original volume of water resulting in a concentration of one twentieth, or 5 mg/l.

The phrase "initial dilution" refers to the dilution achieved at the end of the diffuser jet, usually either at the point where the jet reaches the surface of the body of water or at the point where it has lost its momentum and when rapid mixing ceases. In shallow waters such as the 20 foot depth of all three outfall alternatives the initial dilution is typically reached within about 50 feet of the outfall itself and within two minutes.

Just as there are two sources of momentum to provide dilution for wastewater, there are two fundamental sets of equations which describe the mixing process which results in initial dilution. If the discharge

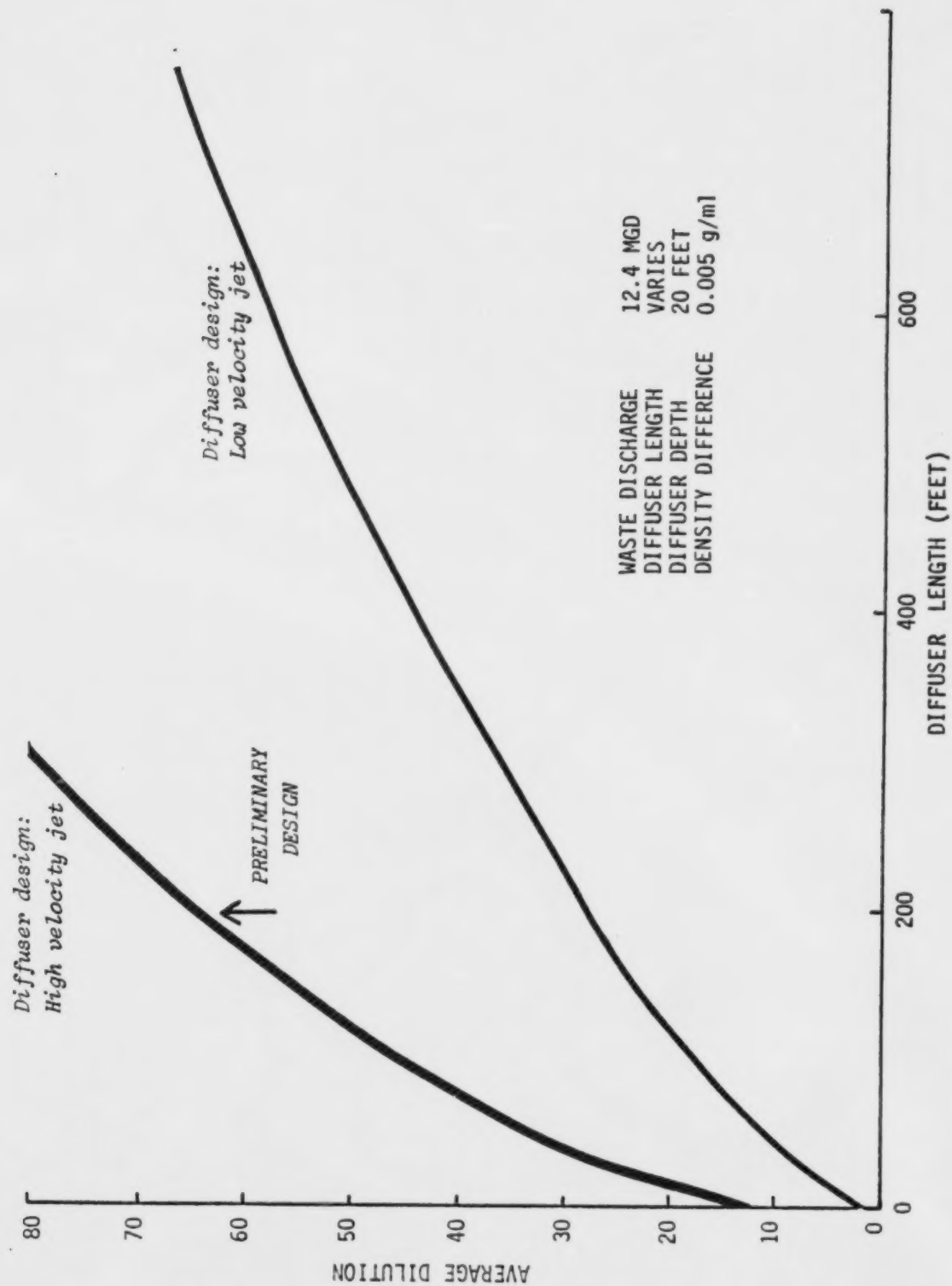
velocity is low, if the volume of wastewater is small compared to the diameter of the diffuser exit port, then buoyancy may be the major source of momentum for mixing. Originally, when diffusers had few ports of large size and were located in the ocean where high ambient water density could be relied upon, buoyancy dilution was most common. Current outfall design, however, stresses the use of high velocity discharge. Although this may require more expensive effluent pumping or diffuser construction, the initial dilution that results is usually twice that if buoyancy alone were the principal source of mixing momentum. The following material will describe the dependency of initial dilution on physical factors of design and environmental conditions and the case between the high velocity and the low velocity jet will be contrasted in order to indicate the range of dilutions which are being considered.

Diffuser Length

One obvious feature of diffuser design is the length of the underwater section from which the waste stream is discharged. Figure 2-2 illustrates the relationship between average initial dilution of the waste and the length of the diffuser section. In this, as in other graphs that follow, the case illustrated is the project as proposed. Typical conditions are selected and only the variable under discussion changes in the graph. When the diffuser is short (10 to 50 feet) the dilution is low, simply because of the high unit loading (cubic feet per second of waste per lineal foot of diffuser). If discharge velocity is held constant as the outfall is extended, the physical increase in the volume for dilution results in a significant increase in initial dilution. Although the actual results will fall between the high and low velocity jets illustrated, the marked improvement in dilution that is available merely by extending the length of the outfall should be kept in mind when considering differences between outfall locations that are described in the subsequent analysis.

Figure 2-2

INITIAL DILUTION WITH DIFFUSER LENGTH



Diffuser Depth

Another factor of outfall design is the depth within the river at which the diffuser will be positioned. Figure 2-3 illustrates the intuitively obvious relationship between increasing depth and increasing dilution. Because of the long trajectory due to horizontal discharge, the high velocity jet is able to achieve significant dilution even in relatively shallow locations. All three alternative outfall sites described in this study discharge at 20 foot depth.

Waste Discharge Rate

Although not an aspect of the design per se, the wastewater flow is an aspect of diffuser operation which will vary--both throughout the day and also over the lifetime of the project. Measured in million gallons per day (mgd) or in cubic feet per second (cfs; one mgd equals 1.55 cfs), the waste stream from the proposed north shore sub-regional treatment facility will vary from only a few mgd during non-peak hours at present populations to many times that number when the project is at capacity. In 1996, the project design year, the average daily dry weather flow is 12.4 mgd and the peak flow is 24.6 mgd. Figure 2-4 shows the effect of changing flow rate on initial dilution. In the low velocity jet case, low flows provide a substantial increase in dilution simply because of the decreased unit loading of wastewater per lineal foot of diffuser length. The high velocity jet shows a similar increase in dilution at very low flows. However, the decline in dilution observed with increasing flow in the low velocity jet is offset in the high velocity jet by the increase in discharge velocity resulting from increased flow through a constant diameter exit port. The preliminary diffuser design provided by the Engineers for this study lies roughly at the minimum in the curve relating dilution to flow rate. This means that variations away from the design condition used in this study (12.4 mgd) will result in very little change in initial dilution.

Density Difference

A fourth factor, environmental rather than design, is the buoyancy of the waste stream. Buoyancy is the result of a difference in density between two fluids. Usually the wastewater is warmer or less saline than the body of water into which it is discharged. The difference is usually very small. In the low velocity case, when buoyancy is expected to provide the major mixing momentum, a low density difference results in a low dilution at the surface (See Figure 2-5). As the density difference increases, the low velocity jet has greater momentum and the initial dilution increases proportionately. In the high velocity case, however, low density difference results in a very slow rise of the waste stream leaving a longer period of time for jet turbulence to dilute the effluent before it reaches the surface. For this reason, increasing density of the ambient fluids result in decreasing dilution at the surface. For the specific outfall proposed, there is a point reached where density difference begins to impart significant momentum to the effluent stream and initial dilution rises in the fashion of the low velocity case. Again, it should be noted that the range of density conditions expected for all three discharge sites in all seasons results in operation on the dilution versus density curve that provides high initial dilution. For the purpose of this study we have selected as typical a difference of 0.005 which yields a conservative estimate of initial dilution.

Figure 2-3

INITIAL DILUTION WITH OUTFALL DEPTH

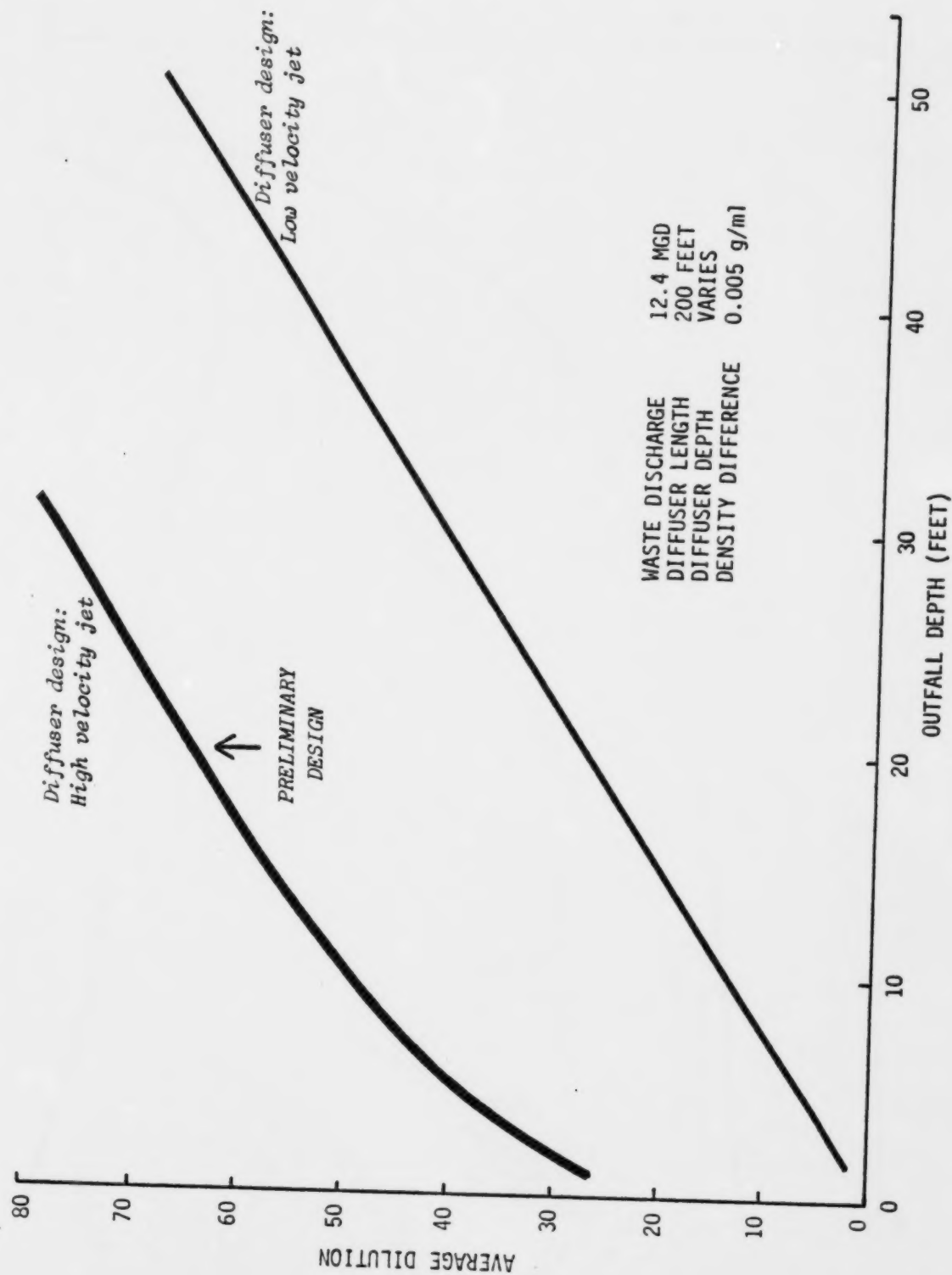


Figure 2-4

INITIAL DILUTION WITH EFFLUENT FLOW

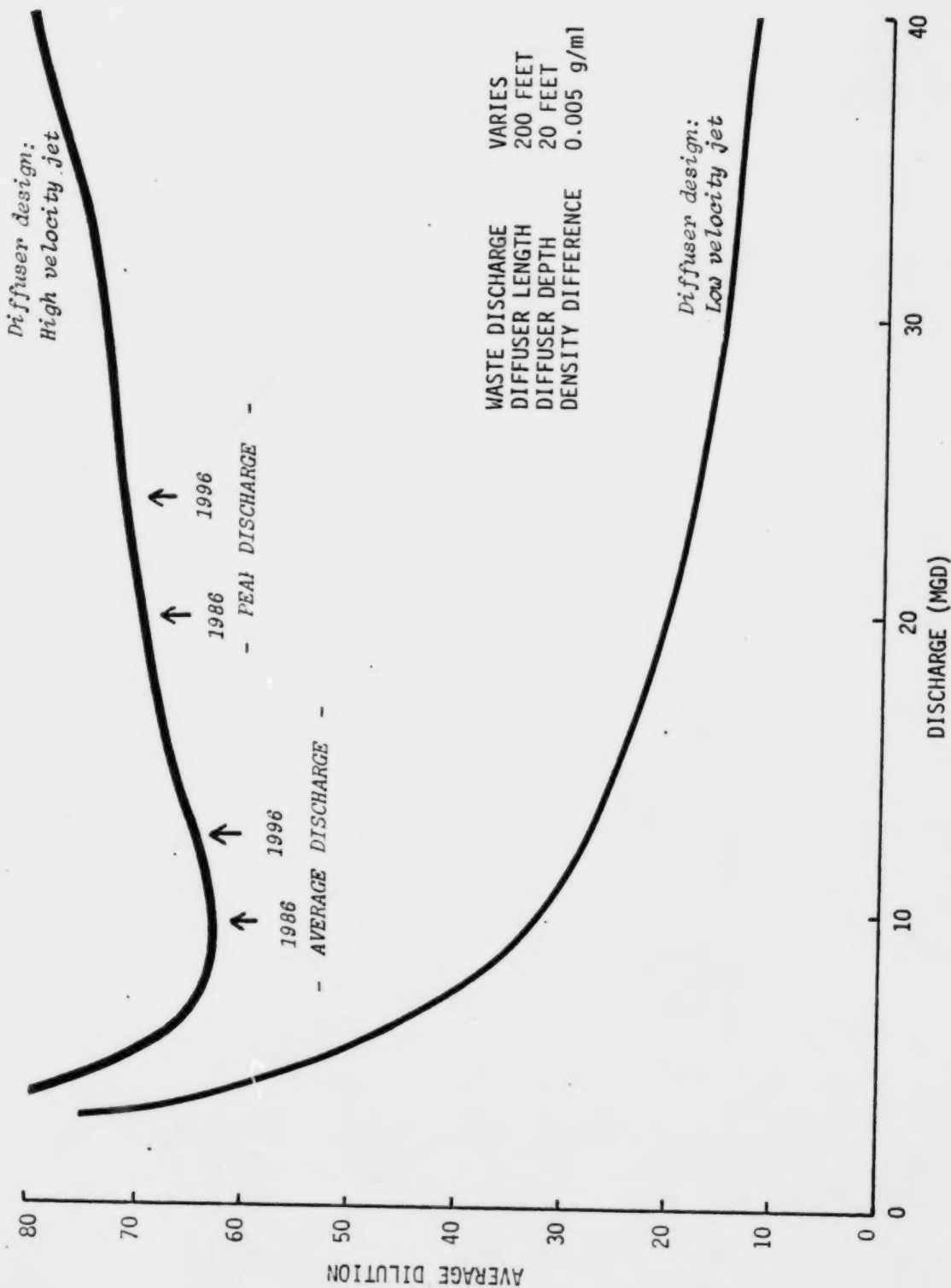
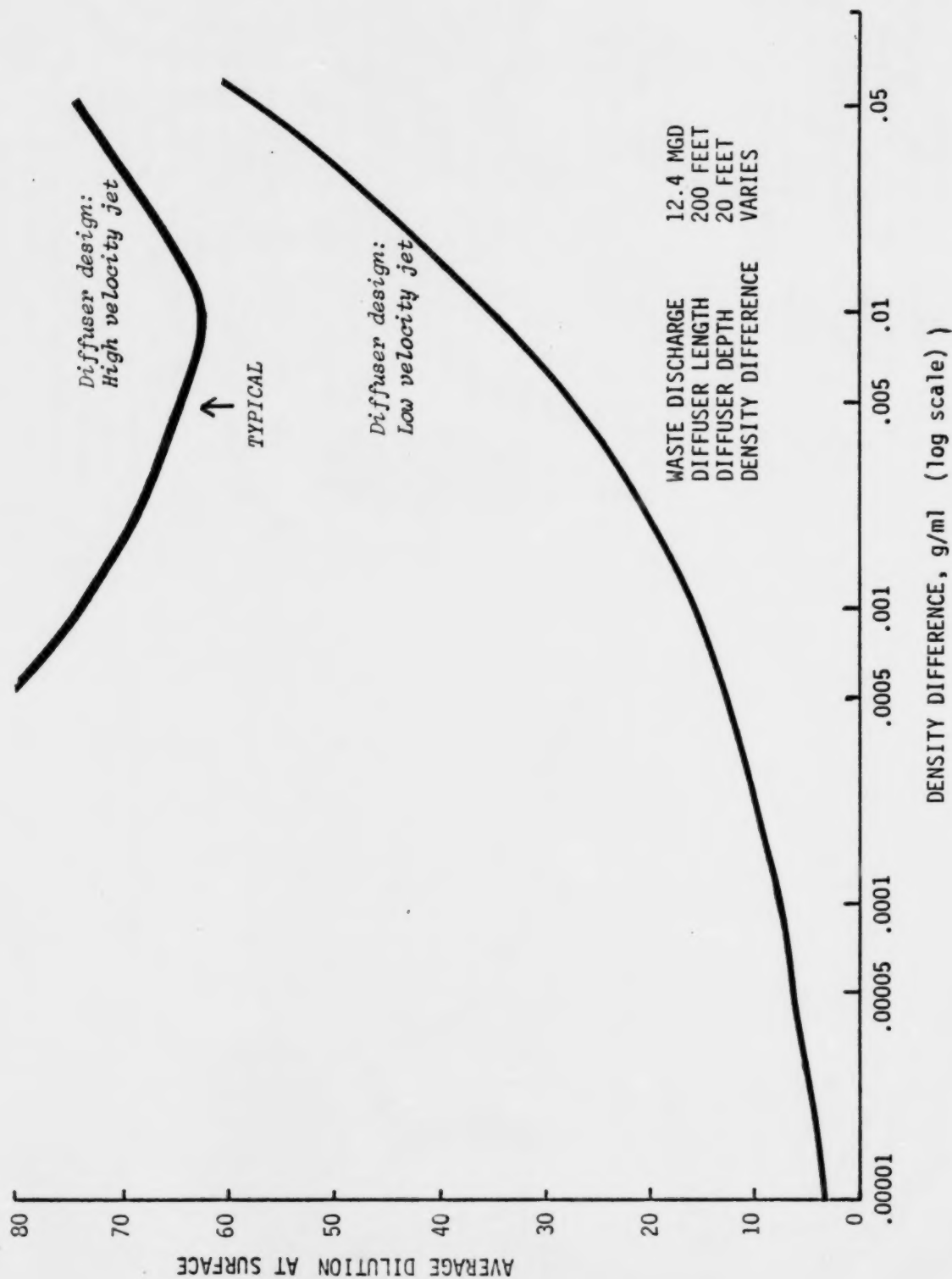


Figure 2-5

INITIAL DILUTION WITH DENSITY DIFFERENCE



PALL

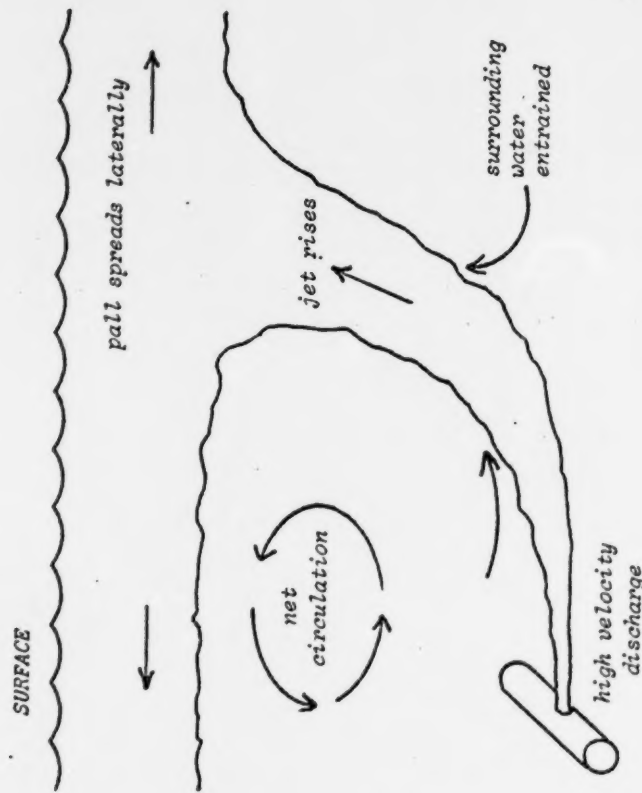
Although the principle of jet dilution is simple in many instances, in this case, its action is severely restricted by two factors. First, dilution on the order of 50:1 requires an influx of surrounding water equal to 50 times the wastewater discharged. In a shallow river, this can amount to a large inflow of water around the base of the diffuser section, and this inflow may entrain a significant quantity of already polluted water. Second, the increased flux resulting from dilution on the order of 50:1 results in a large flow of polluted wastewater above the diffuser. In a shallow river with no current this must soon result in a large cloud or pall of diluted wastewater that will accumulate continuously above the diffuser.

These conditions result in a dramatic decrease in net dilution of the waste stream. As the pall increases in thickness, the effective depth of clean water available for dilution decreases, the last few feet of rise take place within the cloud of polluted water and the initial dilution at the surface is reduced. Similarly, the large requirement for mixing water can cause an internal circulation of waste in the immediate vicinity of a diffuser located in shallow water. Because concentrations of pollutants within the pall are expected to be much higher than would be calculated on the basis of jet equations alone the biological impact assessment which is the purpose of this study must investigate the size, rate of formation, and concentration of pollutants achieved with the pall. See Figure 2-6.

For the purposes of this study the preliminary estimate of diffuser length is 200 feet. With alternating exit ports discharging horizontally to either side, the immediate field of diluted wastewater of the surface will be roughly 200 feet in length and 40 feet in width. In still water, with no ambient current, this field of wastewater will grow as it is augmented by continuing discharge. The growth rate is roughly proportional to the volume of input.

Figure 2-6

PALL



In this case the growth of the pall will follow the dimensions shown in Figure 2-7. The thickness of this blanket of diluted wastewater will be roughly 5 feet in its early stages since that is the approximate thickness of the jet that forms the pall.

Later, as vertical circulation currents are induced by the pumping action of the jet, the pall is expected to descend downwards. With this discharge in 20 feet of water, it is likely that roughly one-half hour of continuous discharge would result in the wastewater column extending from the surface to the outfall on the river bottom, at least within a vicinity of 50 to 100 feet, and minimum dilution within the surface layer will drop to approximately 17:1. At the point when the column of wastewater descends from the surface back to the outfall, dilutions are expected to decline further--roughly 13:1 under the worst condition anticipated for the project.

If the discharge is into a saline, estuarine environment which may become stratified during certain times of the year, the rise of the waste jet will be retarded. Dilution occurring early in the jet's progress entrains denser water from the lower strata of the river. This results in a new jet density which may be less than the upper layer of the river, and in this case the pall will form at some intermediary position between the bottom and the surface (See Figure 2-8). Since the rise to an intermediary position is shorter, initial dilution is less in the case of stratification. Otherwise, a sub-surface pall behaves similarly to a surface pall. The high velocity jet tends to disrupt stratification in the immediate vicinity of the outfall, further reducing any differences.

It should be clear that the formation of the pall and its persistence depends on there being no current in the receiving waters that would shift the waste cloud away from the outfall site. Continuing discharge with no current would naturally

result in a gradually increasing mass of wastewater with dilution approaching zero at the point of discharge. In the shallow estuarine environment of the project discharge, it is the flux of current which prevents such an undesirable waste buildup.

PLUME - EFFECT OF CURRENT

The presence of current is critical to the functioning of a sewage outfall. The current provides a flux of ambient waters which ultimately dilute the wastes according to the proportion of the current flux to the wastewater flux. On a smaller scale current has two important effects: (1) current changes the shape of the jet, (2) current shifts the pall away from the discharge site, forming a plume, where further mixing and dilution take place.

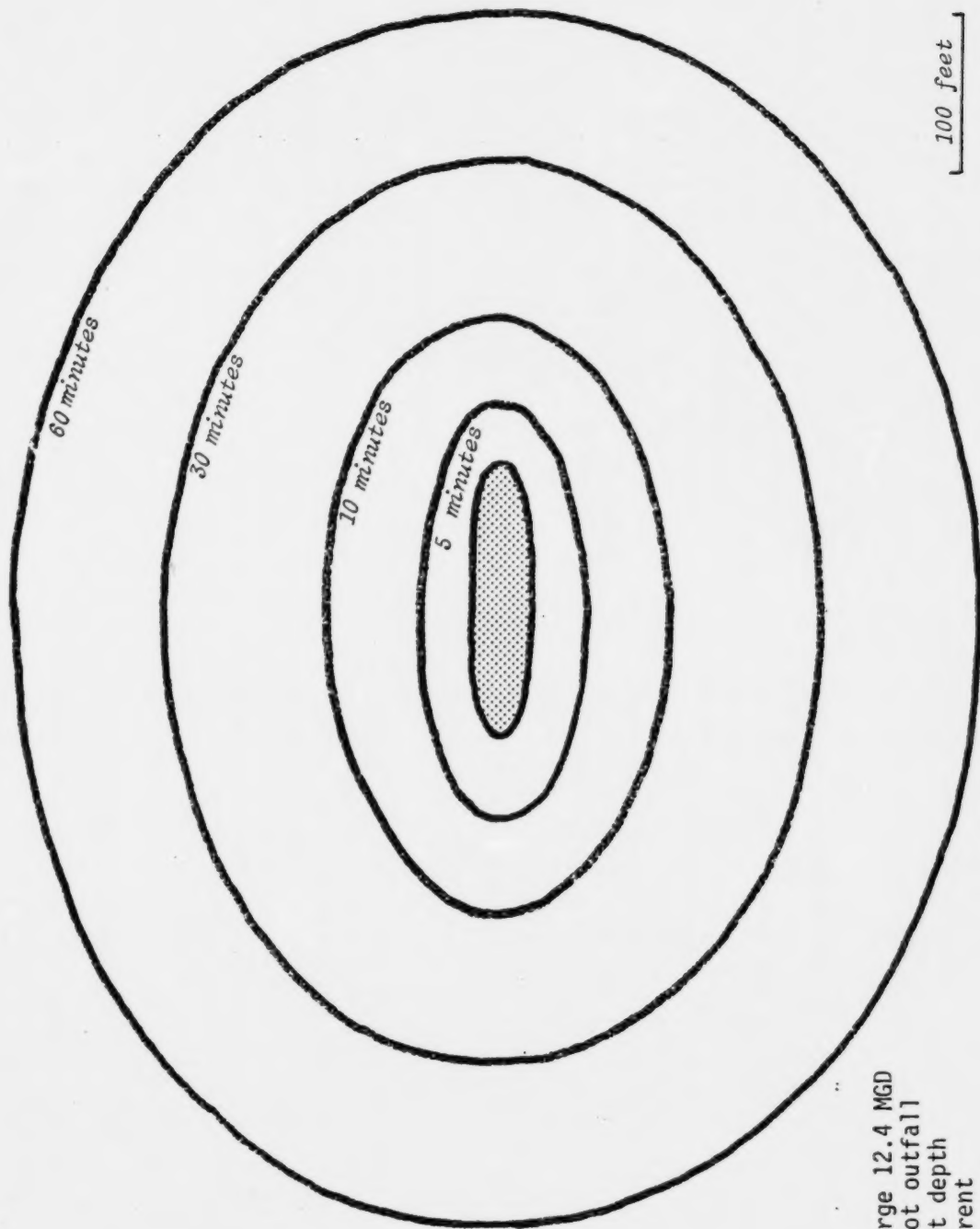
Critical Current

Figure 2-9 shows a jet in quiet water and depicts the change induced as the current increases. The first effect is to lengthen the arc of the jet and to increase the dilution at the surface. Increasing current distorts the jet more and more, bending it toward the river bottom. The pall, normally lying above the jet in quiet water, is also shifted until the rate of pall formation is slower than the rate at which the current shifts the pall away from the discharge site. At this point, the current has bent the jet flat against the river bottom and the pall has disappeared; in its place is a wedge of rapidly diluting wastewater which stretches downstream from the outfall.

The magnitude of ambient current required to effect this transition from jet to wedge is known as the "critical current." The value of critical current depends on parameters of discharge including the momentum of the jet and the momentum of buoyant rise. Typical values for discharge rates of this project in this area are on the order of one-tenth to two-tenths of a knot.

Figure 2-7

PALL FORMATION RATE



discharge 12.4 MGD
200 foot outfall
20 foot depth
no current

Figure 2-8
PALL IN STRATIFIED ENVIRONMENT

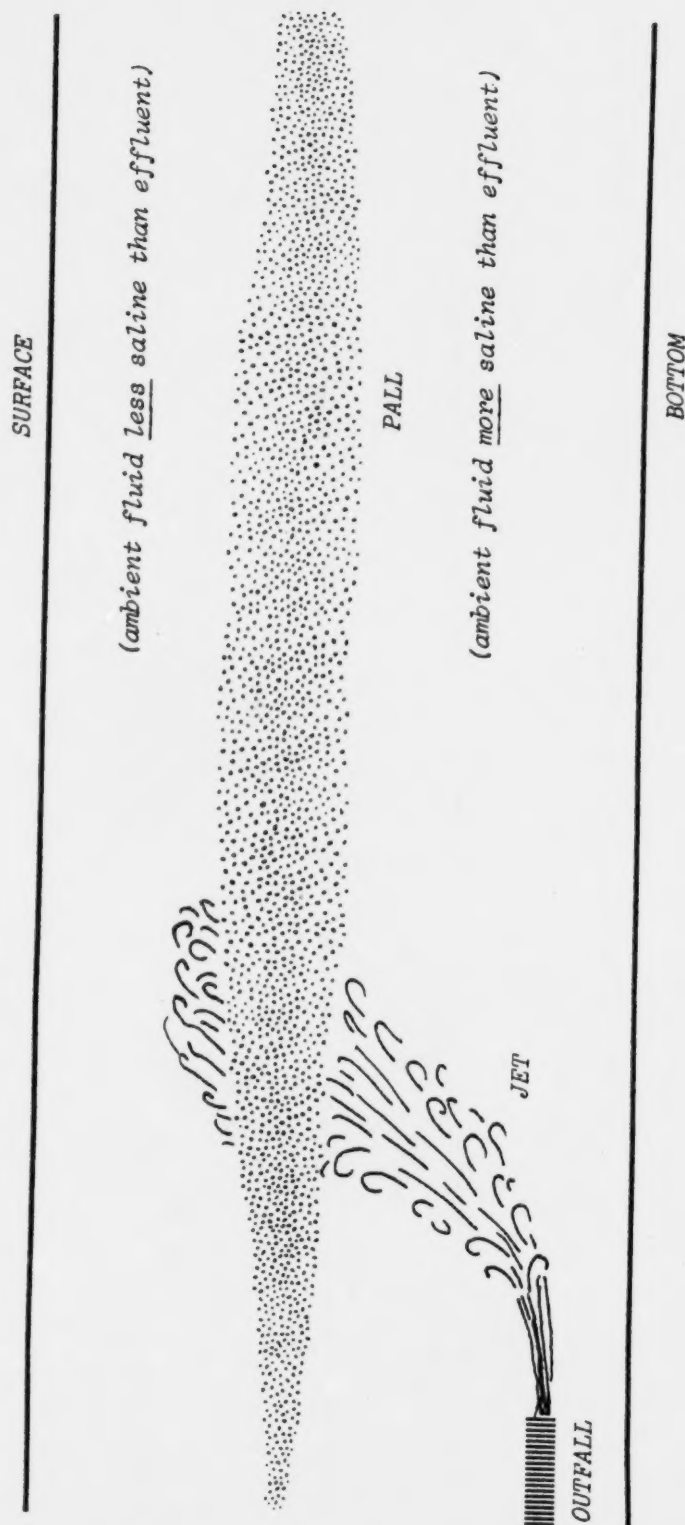


Illustration of a buoyant jet. The ambient density stratification prevents the jet from reaching the surface (adapted from a photograph of a laboratory experiment, Fan and Brooks, 1969).

EFFECT OF CURRENT

A SURFACE

C SURFACE

zone of less
dilution
boundary of
waste field

zero
current

critical
current
(0.10 kt)

BOTTOM

BOTTOM

B SURFACE

D SURFACE

very small
current
(0.02 kt)

strong
current
(> 0.50 kt)

BOTTOM

BOTTOM

2-12

In terms of environmental impact, it is the transition from sub-critical flow (the fall) to critical flow (the rapidly diluting wedge) that determines the local impact of the discharge. It is during the brief intervals of low current that occur in the estuary between the changing of the tides that sub-critical currents allow the formation of a dense pall of waste. Dilution in the wedge is typically so great that the waste will be acceptably diluted under all conditions when the ambient current exceeds the critical level.

Duration of Slack

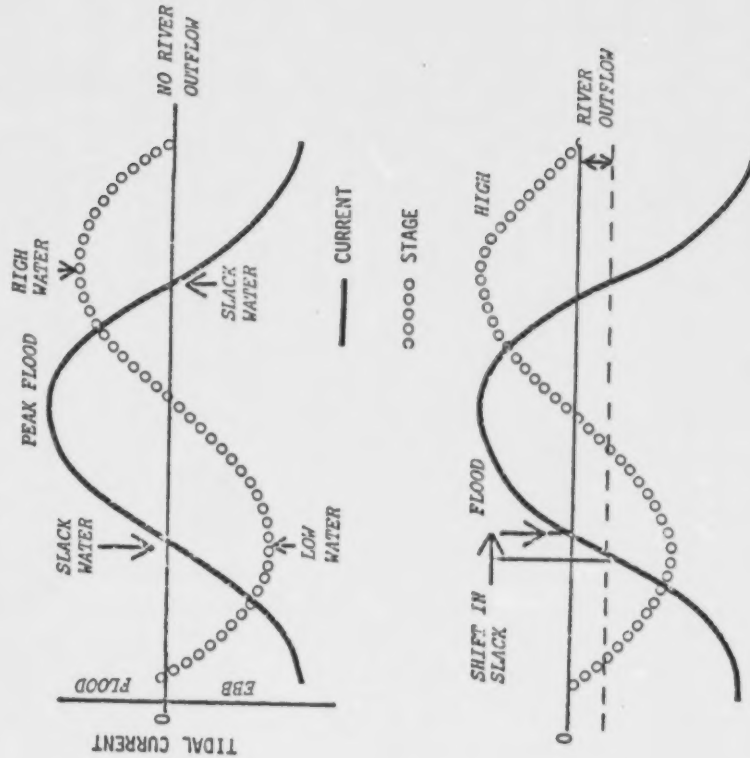
Current in the study area is dominated by tidal change; Figure 2-10 shows the relationship between river current and tidal stage. The upper diagram is for the case where the estuary has relatively simple hydraulics and when there is no net river outflow: then the period of slack water corresponds to the maximum and minimum tidal stages. If there is river outflow the net current is non-zero as in the second diagram. This has the effect of shifting the phase of the current cycle relative to the elevation cycle. Far up the estuary, attenuation induces additional phase changes. In the study area a shift of as much as two hours is common, with slack water occurring up to two hours after the changing of the tide.

As far as wastewater discharge is concerned, however, the important fact is the function of current around the point of slack water is nearly a straight line. The duration of any period with current less than a given value is readily determined. Over a wide range of net river outflow, the phase shift induced in the current cycle results in very little change in the actual duration of slack water--the effect of river outflow is merely to change the time at which slack water occurs.

The duration of low current during a tidal cycle

Figure 2-10

RELATIONSHIP BETWEEN TIDAL CURRENT AND TIDAL STAGE



is inversely proportional to the magnitude of peak current which occurs during that cycle. Peak current itself is a function of the degree of change in the high and low tide, which is a function of the complex lunar-solar tidal cycle. Figure 2-11 shows the approximate statistical distribution of peak currents at Golden Gate. With the proper current multipliers these figures can be used to give the expected frequency of various peak currents anywhere within the Bay estuary.

Given any value of peak current and given a criterion of low flow, it is possible to calculate the duration of the interval during which the current either upstream or downstream in the river will be less than the criterion current value.

Figure 2-12 shows the duration of "slack" as a function of criterion current for various values of expected peak current. For peak currents over the range of one-half to three knots, there is a dramatic variation in the duration of slack. Typically, however, the period of low flow lasts for a fraction of an hour up to two hours out of each 6½ hour portion of the tidal cycle. This approach allows the statistical determination of the period during which a sub-critical current will be present at the outfall site and during which the pall may be allowed to form.

Once the pall has formed, however, it is necessary to know the manner in which the current will transport the cloud of waste away from the outfall site and ultimately mix it with the body of the river. This further mixing is called secondary dilution. Flow through any channel induces both horizontal and vertical turbulence which promotes lateral mixing. In a river which has tortuous channels and an uneven bottom, the magnitude of transverse mixing may become quite high. Transverse currents are established by only slight net flows and indeed may be greatest during so called "slack" water when momentum reversal causes large eddies and turbulence. For this reason, transverse mixing is essentially a matter of time rather than a function of current or distance displaced.

Figure 2-11

STATISTICAL DISTRIBUTION OF PEAK CURRENTS AT GOLDEN GATE

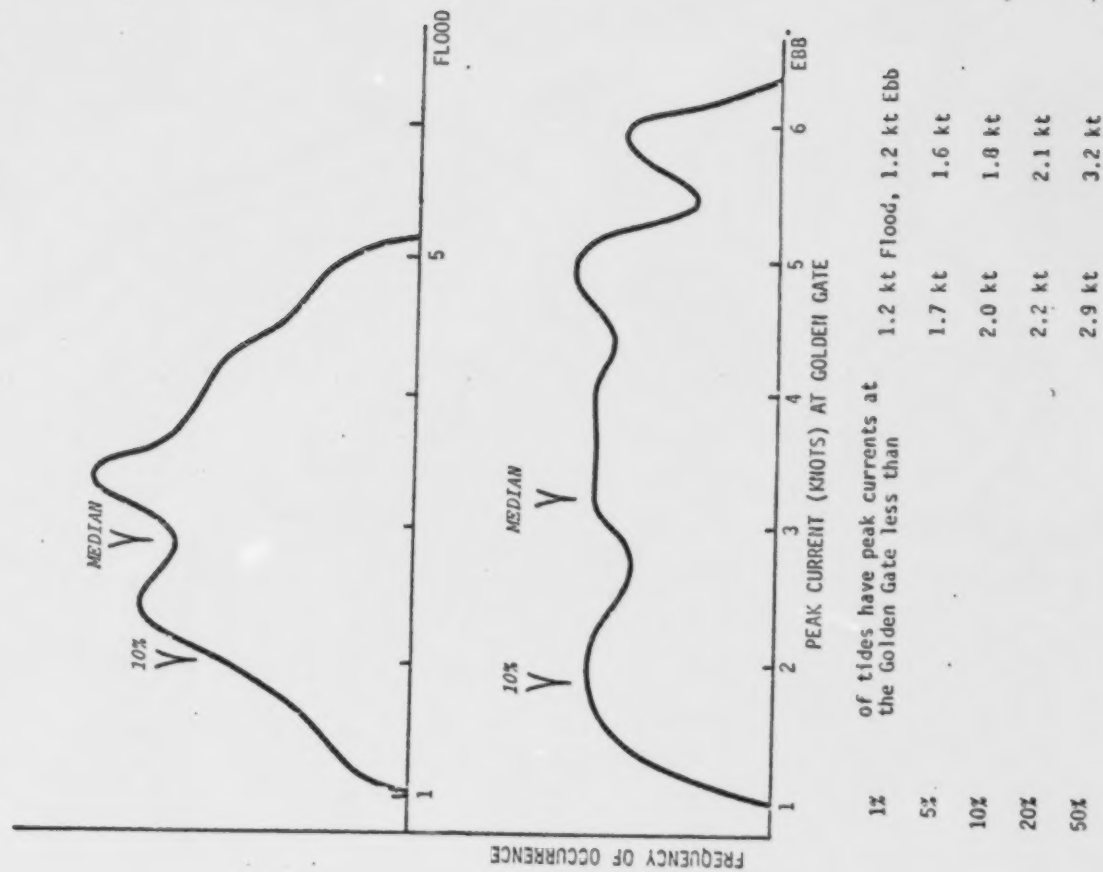
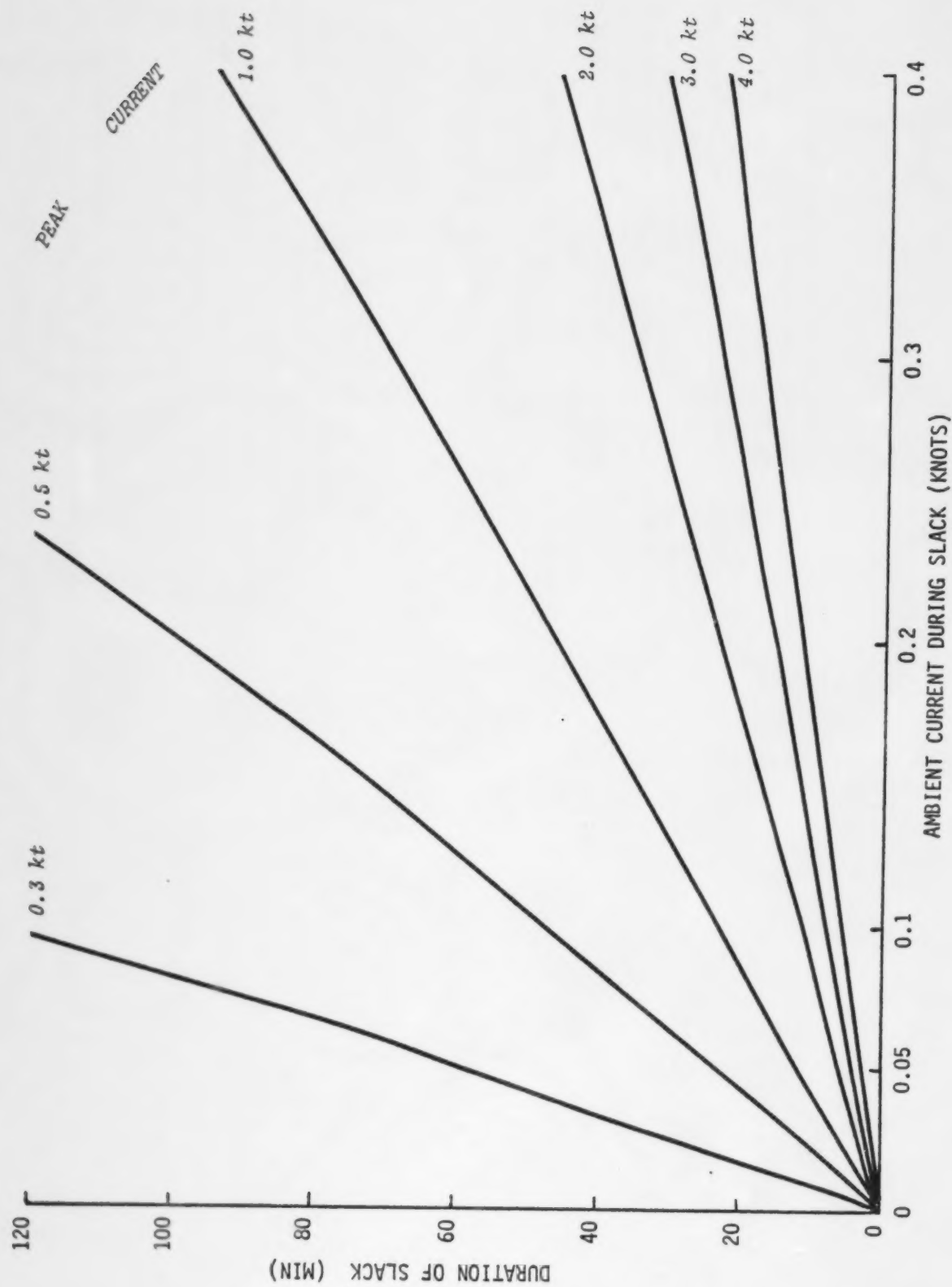


Figure 2-12
DURATION OF SLACK WITH DIFFERENT PEAK CURRENTS



Within two hours, secondary dilution is roughly 5:1. Dilution is multiplicative: if initial dilution were 20:1 and secondary dilution is 5:1, then overall dilution is 100:1. The secondary dilution is achieved by further entrainment of receiving water and is thus accompanied by a spread of the waste plume.

In channels such as are represented by the outfall sites, the ratio of horizontal to vertical mixing varies from 7:1 to 3:1 meaning that the lateral spread in some instances may be seven times faster than the vertical spread. Since the river is so shallow throughout most of its extent, however, even retarded vertical mixing means that the waste plume will be nearly complete throughout the vertical section of the river within a few hundred feet of the discharge point.

SLUG - ULTIMATE DISPERSION

Once dilution has occurred to the degree that the plume has lost its distinct character, waste is thoroughly dispersed throughout one segment of the river as a slug. This may still be many miles from the ocean, and it may take several days or even weeks for the majority of the pollutants to be eliminated from the tidal system. The mechanism of elimination is the constant tidal influx of unpolluted water and efflux of water bearing a waste load. The exact characteristics depend upon the volume, length, tidal prism and distance from the ocean of the several segments in which the waste slug is located. This was the subject of a computer model presented in the draft EIR/EIS for this project and is not the topic of the local, short-term impact study discussed here.

ALTERNATIVE WASTEWATER DISCHARGE SITES

REGIONAL SETTING

The three discharge alternatives are all located on the Sacramento-San Joaquin River system which flows into the northern portion of San Francisco Bay. Altogether the bay-river complex constitutes a large estuary. Fresh water input from the Sacramento amounts to 30 million acre-feet per year. Seasonal variations in rainfall are responsible for fluctuations in fresh water outflow, ranging from 6,000 to 60,000 cubic feet per second (cfs). The tides at the mouth of the estuary, the Golden Gate, are also variable but typically range from two feet to seven feet and provide a strong driving force for water movement within the estuary. Tidal volumes at the Golden Gate amount to a salt water flow of over two million cfs.

Although the area of concern in this study lies 45 to 55 miles upstream from the Golden Gate, tidal action is still strong, providing currents of one knot or better which change direction four times a day with the tidal cycle. Tidal action is attenuated by the distance upstream, yet tidal flow in the study area still amounts to several hundred thousand cfs and makes the tide and tidal current the dominant factor in local hydraulic movement of water.

The New York Slough discharge site proposed for the industrial shore sub-regional facility located between the cities of Pittsburg and Antioch (see Figure 3-1). One alternative to the proposed New York Slough outfall is the extension of the outfall sewer across New York Slough by syphon and over Browns Island to a discharge point north of Browns Island on the Sacramento River. Another alternative involves location of the sub-regional treatment facility ten miles to the west, in the community of Shore Acres, with discharge to the Sacramento at the site of the existing outfall from County Sanitation District 7A & B.

SALINITY INTRUSION

The tremendous tidal flux through the Golden Gate carries salt water far up the branches of the San Francisco Bay estuary. One aspect of this salt water intrusion which affects outfall functioning is variation in salinity of the receiving waters. The magnitude of saline intrusion at any point is a function of the balance between tidal influx and fresh water efflux. Figure 3-2 shows the gradient of salinity for several years of differing river flow. The variation between wet and dry years represents a twofold difference in peak salinities during the summer. The Shore Acres site, located ten miles downstream from both the New York Slough and Browns Island sites, experiences a typical ambient salinity of ten parts per thousand (ppt). Typical concentrations in the vicinity of Browns Island and New York Slough are 5 ppt.

A second aspect of saline intrusion is the formation of vertical stratification layers within the estuary. As salt water is brought in by the tide, its greater density causes it to sink below the outward flow of fresh water. There is usually mixing along the interface between the salt wedge and the fresh water cover layer, but the resulting gradient in density can be quite sharp at times. This effect is most pronounced during the winter when fresh water outflow is the greatest and at the end of flood tide when the salt wedge has been forced up the estuary to its greatest extent. Figure 3-3 shows the complex changes in salinity gradient that may be caused by variations in the river bottom topography. In this instance, the shoaling that accompanies the widening of the river below Chippis Island creates a barrier to intrusion of the salt wedge and results in a dramatic change in the saline gradient. New York Slough and Browns Island are above this barrier; Shore Acres is downstream. Factors such as this combine with the highly variable effects of the tidal cycle to make predictions of the exact ambient salinity in the vicinity of a discharge point difficult. In the subsequent analysis,

Figure 3-1

REGIONAL SETTING AND OUTFALL LOCATIONS

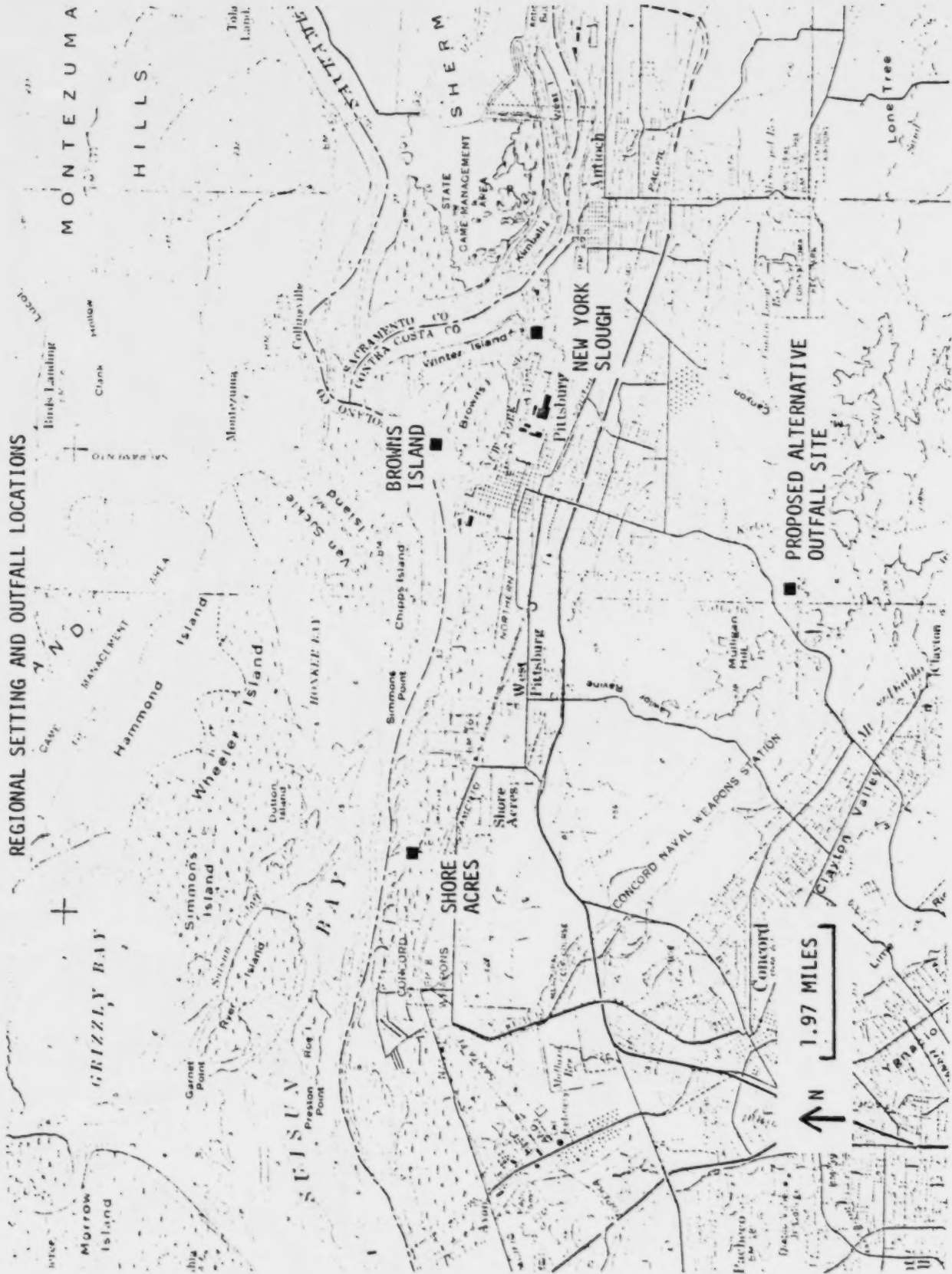


Figure 3-2

SALINITY GRADIENT
SEPTEMBER AVERAGE CONCENTRATIONS

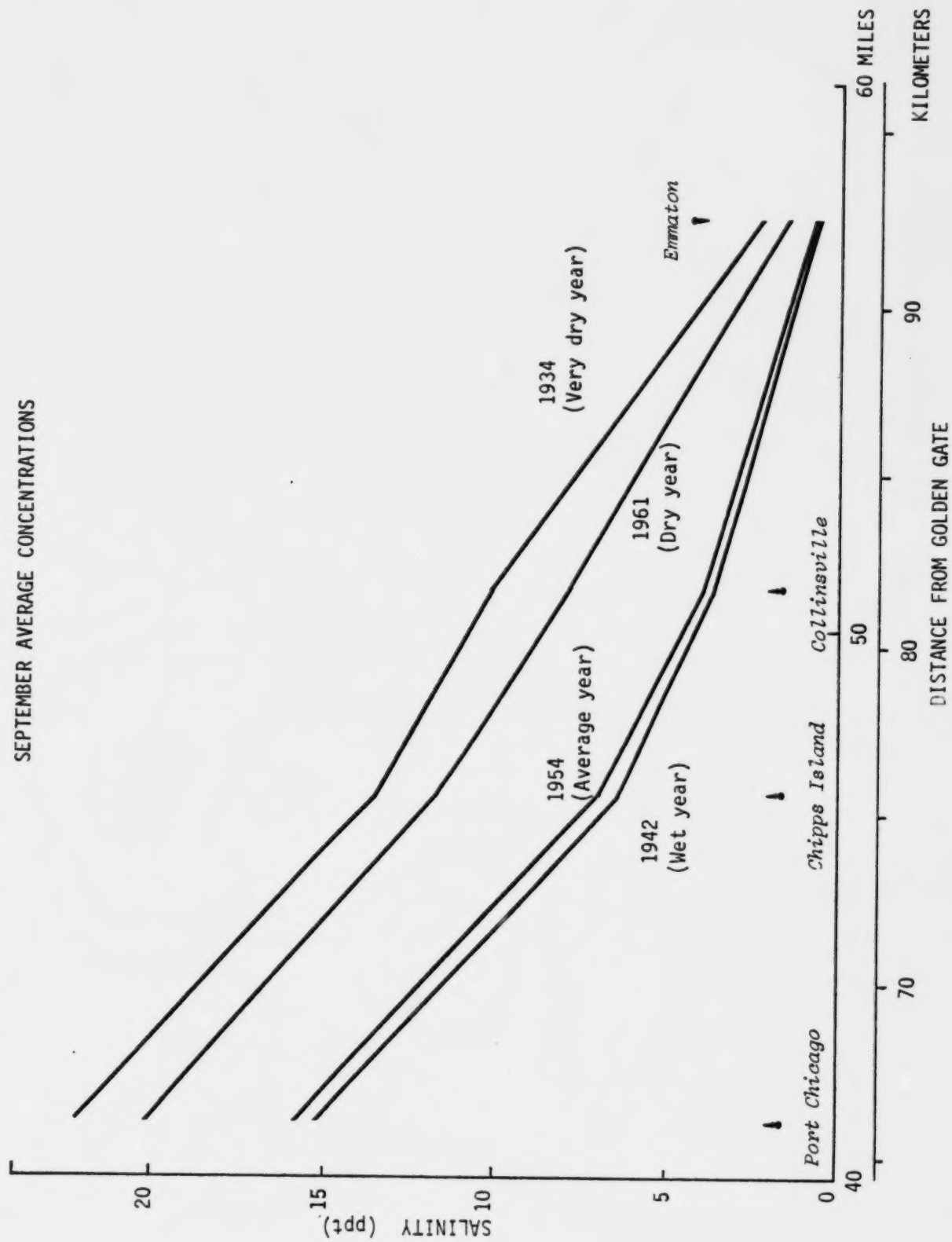
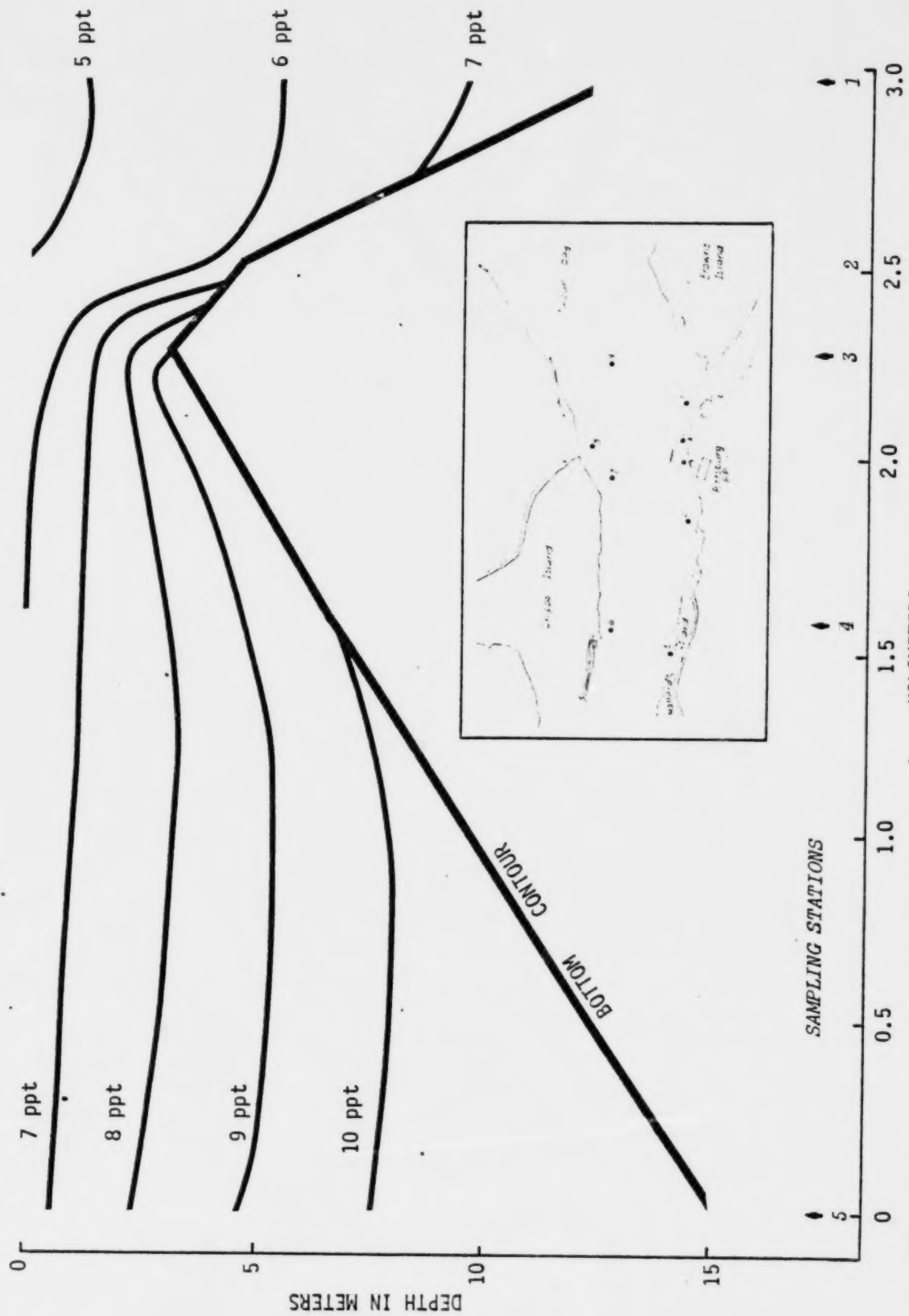


Figure 3-3

SALT WEDGE: TRANSECT OF SALINITY FROM CHIPPS ISLAND TO BROWNS ISLAND



Adapted from PGE Pittsburg Power Plant Study

however, it appears that the effects of tidal current dominate and that variations in salinity result in relatively little change in dilution of the wastes (See Figure 2-6).

NEW YORK SLOUGH

New York Slough is a large channel of the San Joaquin River which essentially provides a shortcut to the Sacramento for San Joaquin waters around Browns and Winter Island. This shortcut is used as a ship channel with a 30 foot depth maintained by the U. S. Army Corps of Engineers (USACE). The south bank of New York Slough is also the industrial waterfront for the city of Pittsburg.

The 30 foot depth in New York Slough is moderate by comparison with other channels of the river; its width is narrow, typically less than 1000 feet (see Figures 3-4 and 3-5). Yet because of its straight alignment, its low aspect ratio (depth divided by width) and its "shortcut" position relative to the Sacramento and the San Joaquin, New York Slough carries a surprising volume of water. One-third to one-half of the tidal exchange and river outflow from the San Joaquin enters the eastern reach of New York Slough where the proposed discharge would be located. Currents in the slough due to tide are typically 0.3 times the currents expected for the tidal cycle at the Golden Gate. Field measurements in New York Slough show that the current profile horizontally and vertically is quite uniform. This is to be expected in a channel of little curvature with a uniformly low aspect ratio along its length. The effect of river outflow as noted in Section 2 is principally to shift the phase of tidal current cycle and to increase the disparity between peak flood tide (incoming and peak ebb tide outgoing) current. See Figure 3-6.

The dominant feature of New York Slough which adversely affects the location of a wastewater outfall is the narrow channel width and the heavy shipping

and maintenance dredging activity. For these reasons the diffuser in New York Slough is proposed to be oriented parallel to the shore and hence parallel to the current in the receiving water. This orientation, needed to prevent interference with the ship channel, reduces the effective length of the discharge under conditions of high ambient current.

BROWNS ISLAND

Browns Island forms the north boundary of New York Slough and separates that channel and the San Joaquin from the Sacramento River north of Pittsburg. The Browns Island alternative would require extensive pipeline construction to reach the north shore of Browns Island, where the Sacramento main channel is wide nearly 1 mile wide and up to 60 feet deep. (See Figures 3-7 and 3-8.) This results in a large cross-section, yet the current of water passing through the main channel above Browns Island is large due to the combined flows of the Sacramento and that portion (one-half) of the San Joaquin which flows eastward around Winter Island.

Tidal current is roughly 0.3 times the current expected at the Golden Gate for any given tidal cycle. Field measurements indicate that the current profile, both transverse and vertical, is fairly uniform throughout the cross-section north of Browns Island. This is significant since the diffuser must be located at the edge of a shallow area extending 2000 feet from the shore of Browns Island. The fact that there is good current movement over these shallows indicates that there are no stagnant areas within the immediate vicinity of this outfall location. This also means, however, that the segment of combined river flows passing through the channel north of Browns Island which will ultimately be directed into the San Joaquin probably extends half way across the channel at this point and includes the flow of river water that crosses the diffuser site. On a flood tide then, this water will be directed into the San Joaquin rather than into the Sacramento unless mixing is complete within the space of one mile. Analysis indicates that is not the case.

Figure 3-4
DIFFUSER LOCATION AND RIVER BOTTOM TOPOGRAPHY: NEW YORK SLOUGH

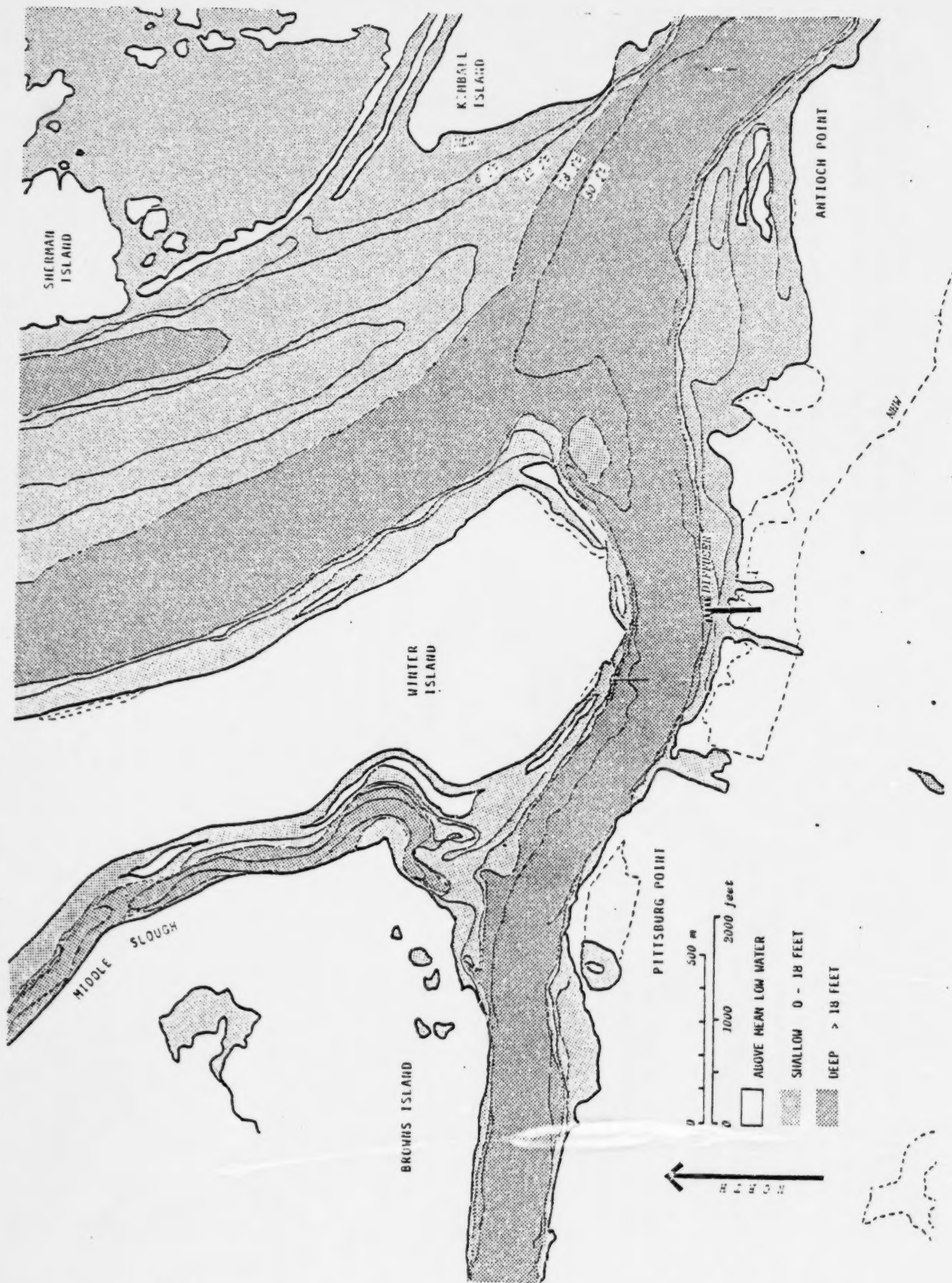


Figure 3-5

NEW YORK SLOUGH CROSS SECTION

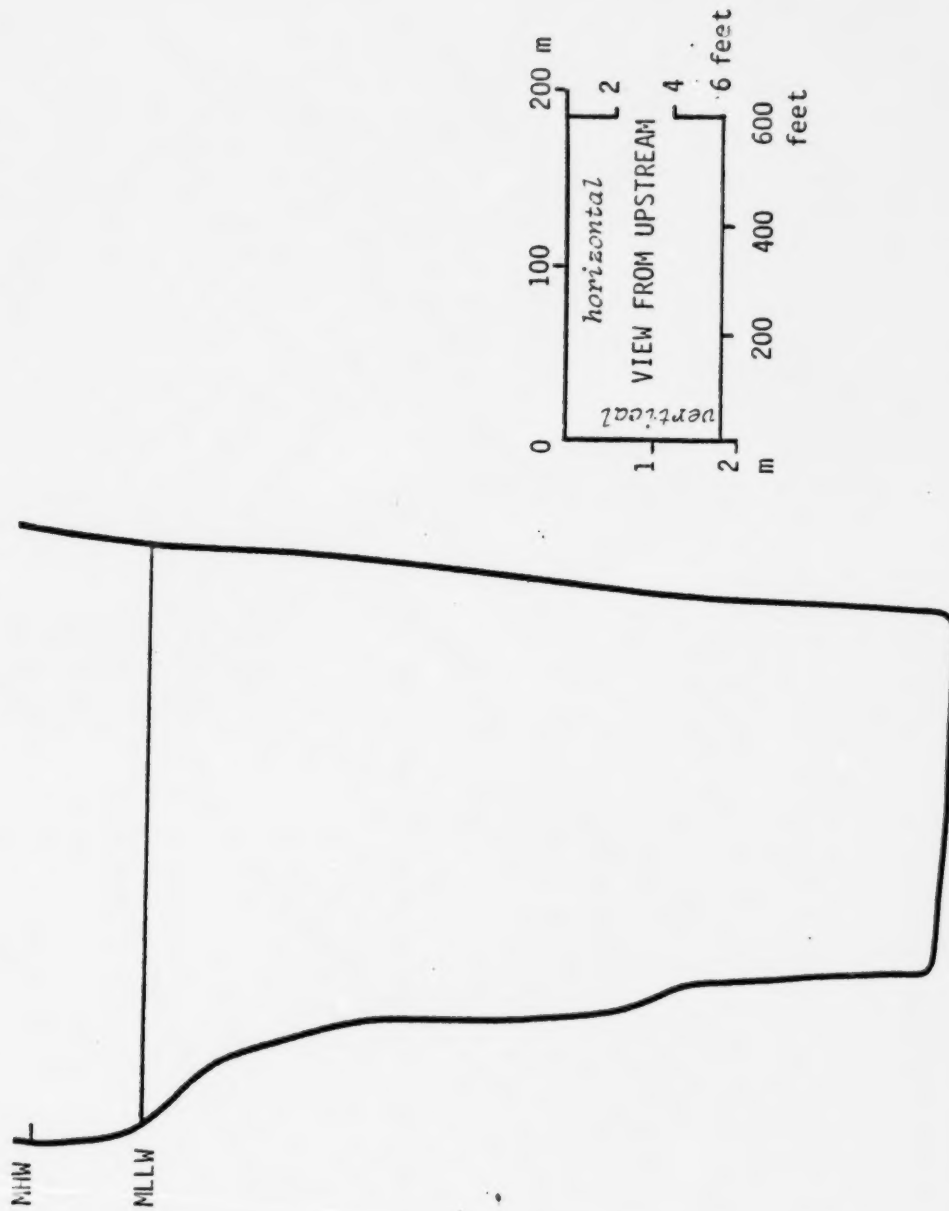


Figure 3-6
PHASE SHIFT OF TIDAL CURRENT AND STAGE
AT NEW YORK SLOUGH AND BROWNS ISLAND

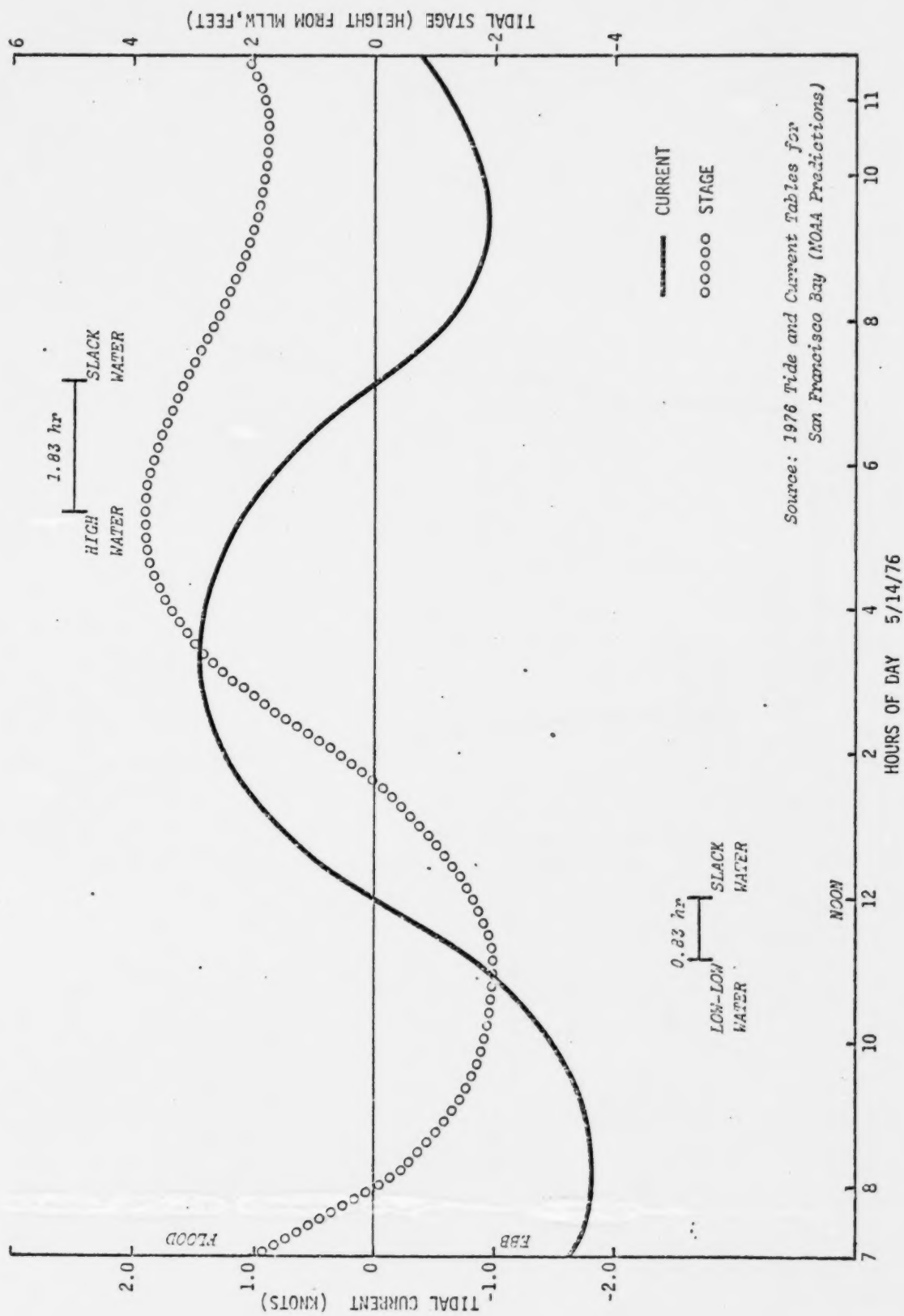


Figure 3-7
DIFFUSER LOCATION AND RIVER BOTTOM TOPOGRAPHY: BROWNS ISLAND

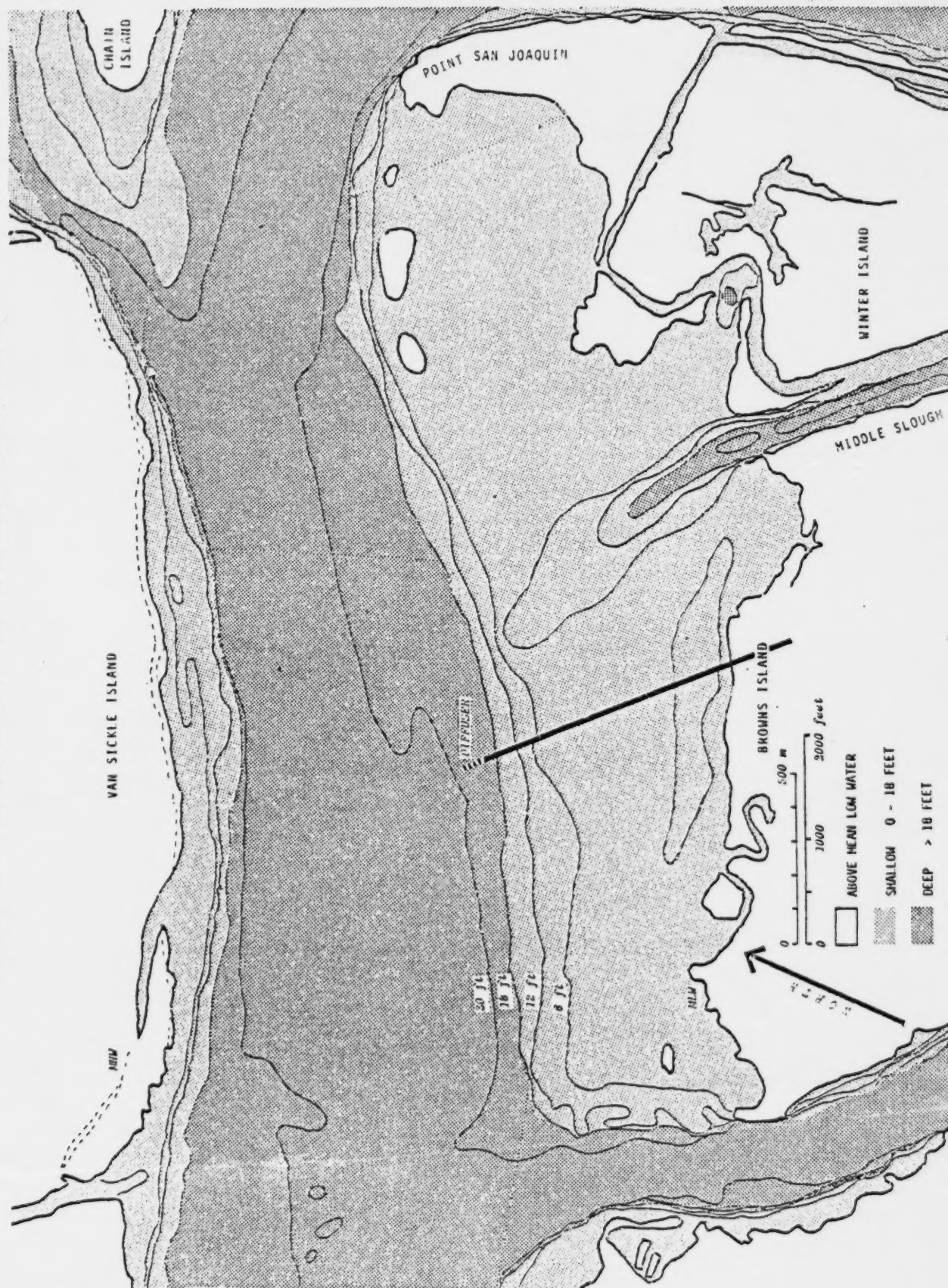
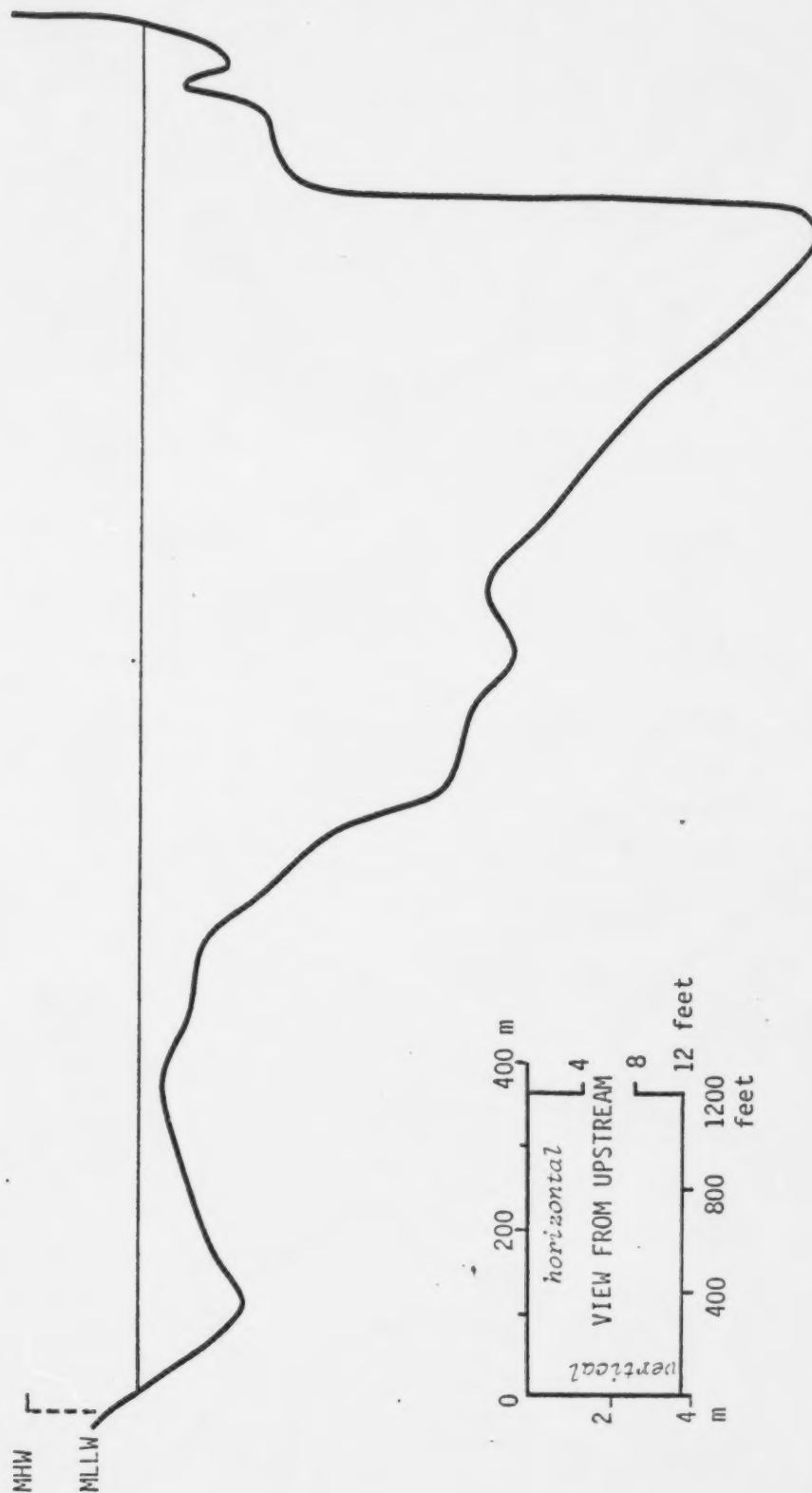


Figure 3-8
BROWNS ISLAND CROSS SECTION



SHORE ACRES

The Shore Acres discharge would occur in the combined Sacramento-San Joaquin River west of Chipps Island opposite Honker Bay. There is a minor channel immediately opposite Shore Acres which appears to be the residual of an ancient flow pattern of the river. Figures 3-9 & 3-10 show the small size of this channel and illustrate the partial blockage from shoaling at the eastern end.

Although the current in the main channel at this point is strong (nearly 0.5 times the cycle current at the Golden Gate), field measurements indicate that the corresponding current in the side channel opposite Shore Acres is quite weak and variable. The sharp curve of the side channel produces the strongest currents within a few feet of shore. These drop off quite rapidly and become confined to surface flow at the north side of the side channel over the sand banks. Although insufficient data are available to make a precise prediction, field measurements and a consideration of flux in the cross section indicate that a current multiplier of 0.2 is appropriate for the side channel at Shore Acres. (See Figure 3-11.)

It is conceivable that the Shore Acres discharge point could be improved by extending the outfall sewer 3000 feet to the west to discharge at Middle Point into the main channel. If this were the case the current regime for Shore Acres would resemble that for Browns Island outfall. This refinement was not included in the scope of the present study. In the light of the conclusions of this study it may be considered within the decision making process by comparison to the documentation provided for the other sites.

Figure 3-9
DIFFUSER LOCATION AND RIVER BOTTOM TOPOGRAPHY: SHORE ACRES

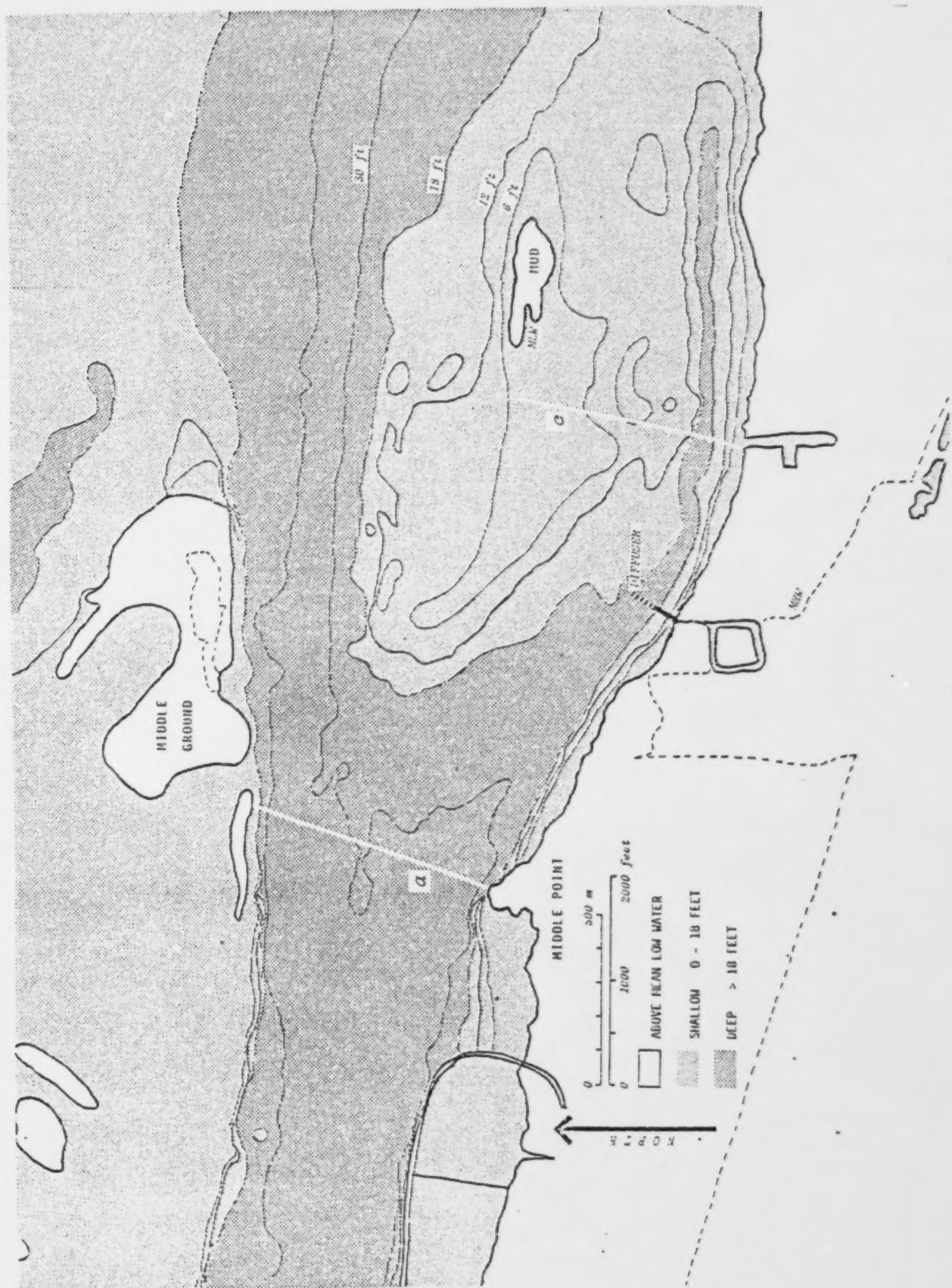


Figure 3-10 (a)

SHORE ACRES CROSS SECTION DOWNSTREAM FROM OUTFALL
(See Figure 3-9 for location.)

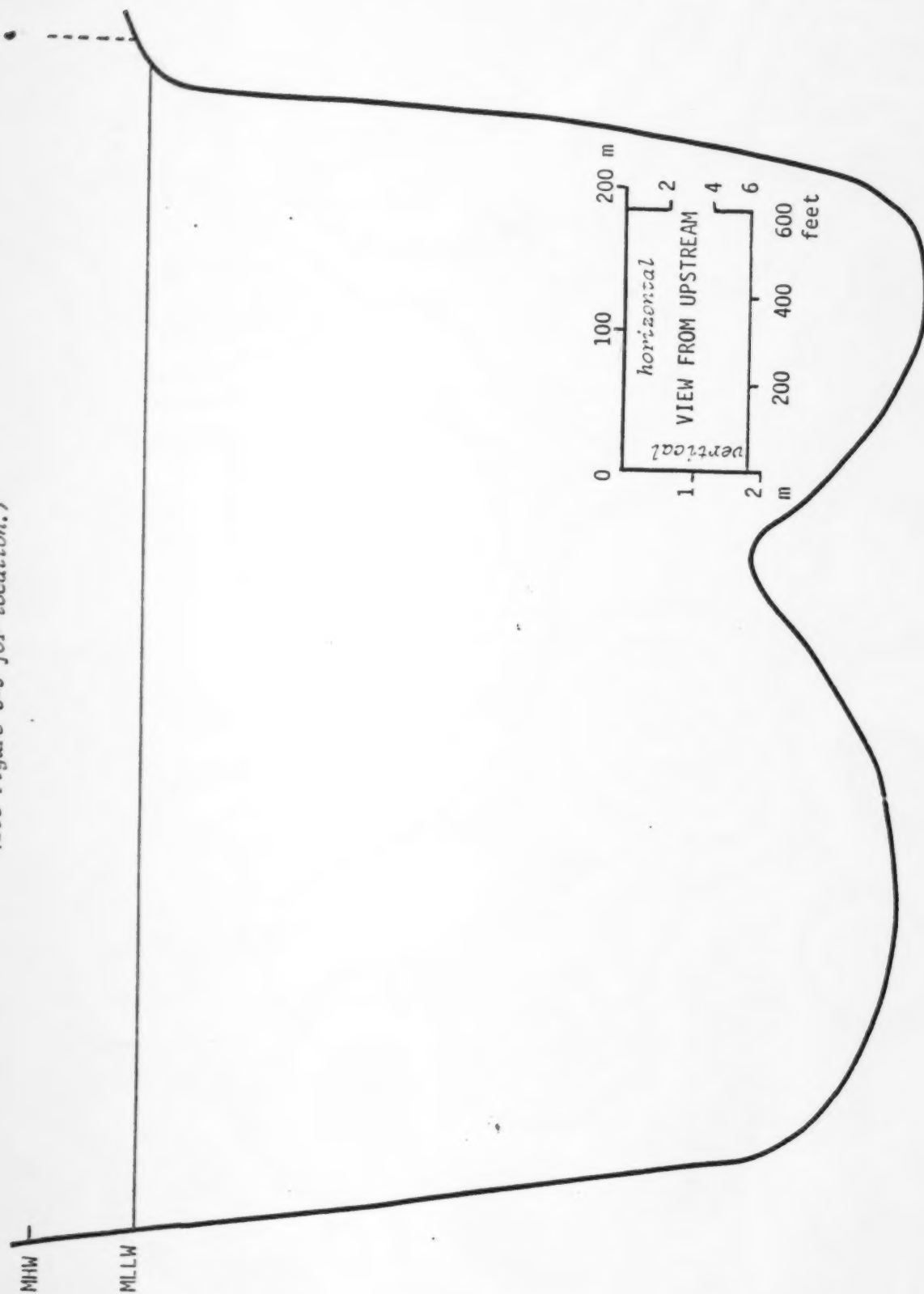


Figure 3-10 (b)
SHORE ACRES CROSS SECTION AT OUTFALL

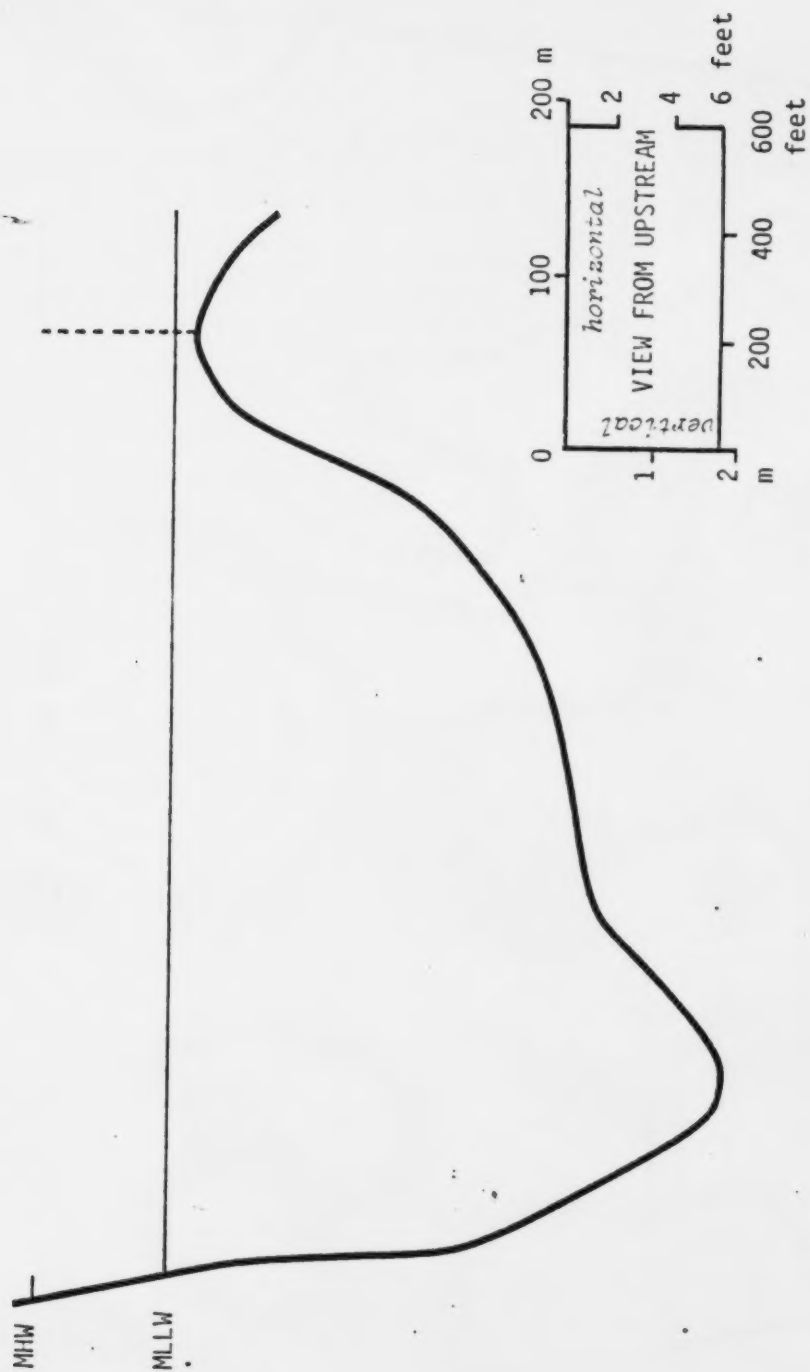


Figure 3-10 (c)

SHORE ACRES CROSS SECTION UPSTREAM FROM OUTFALL

(See Figure 3-9 for location.)

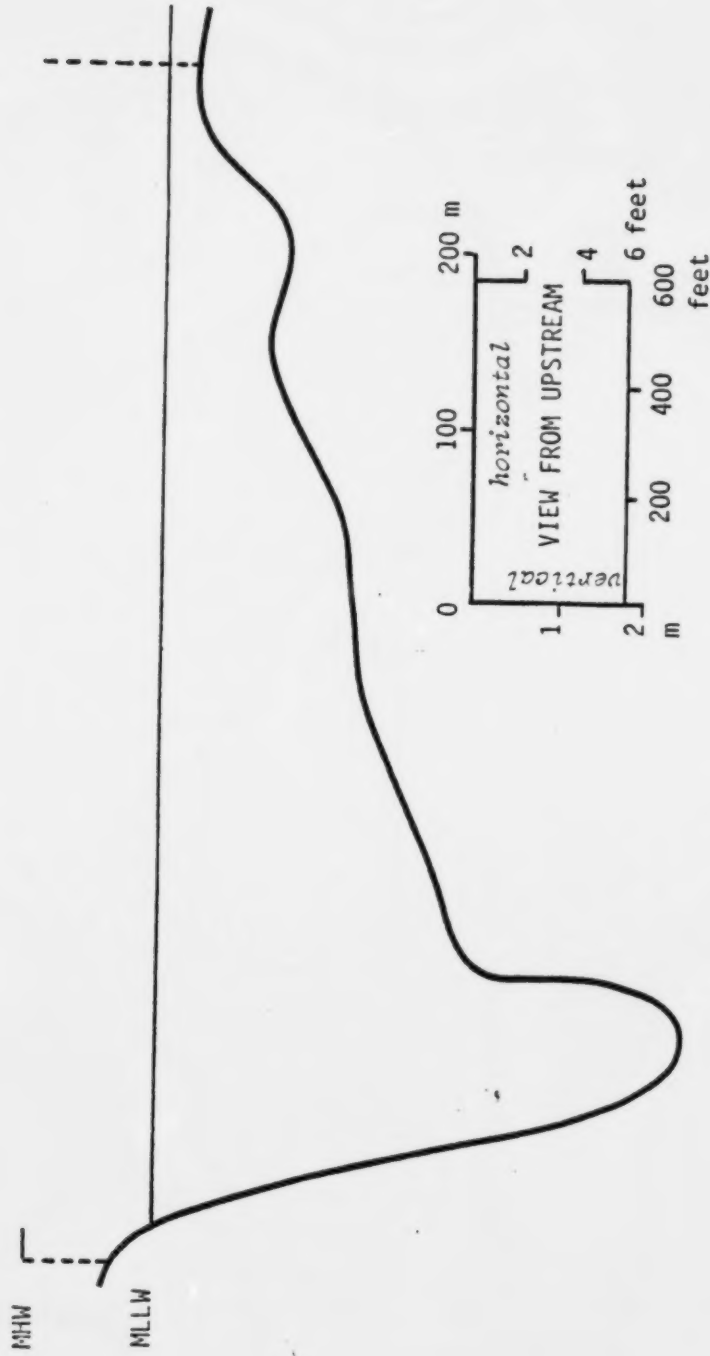
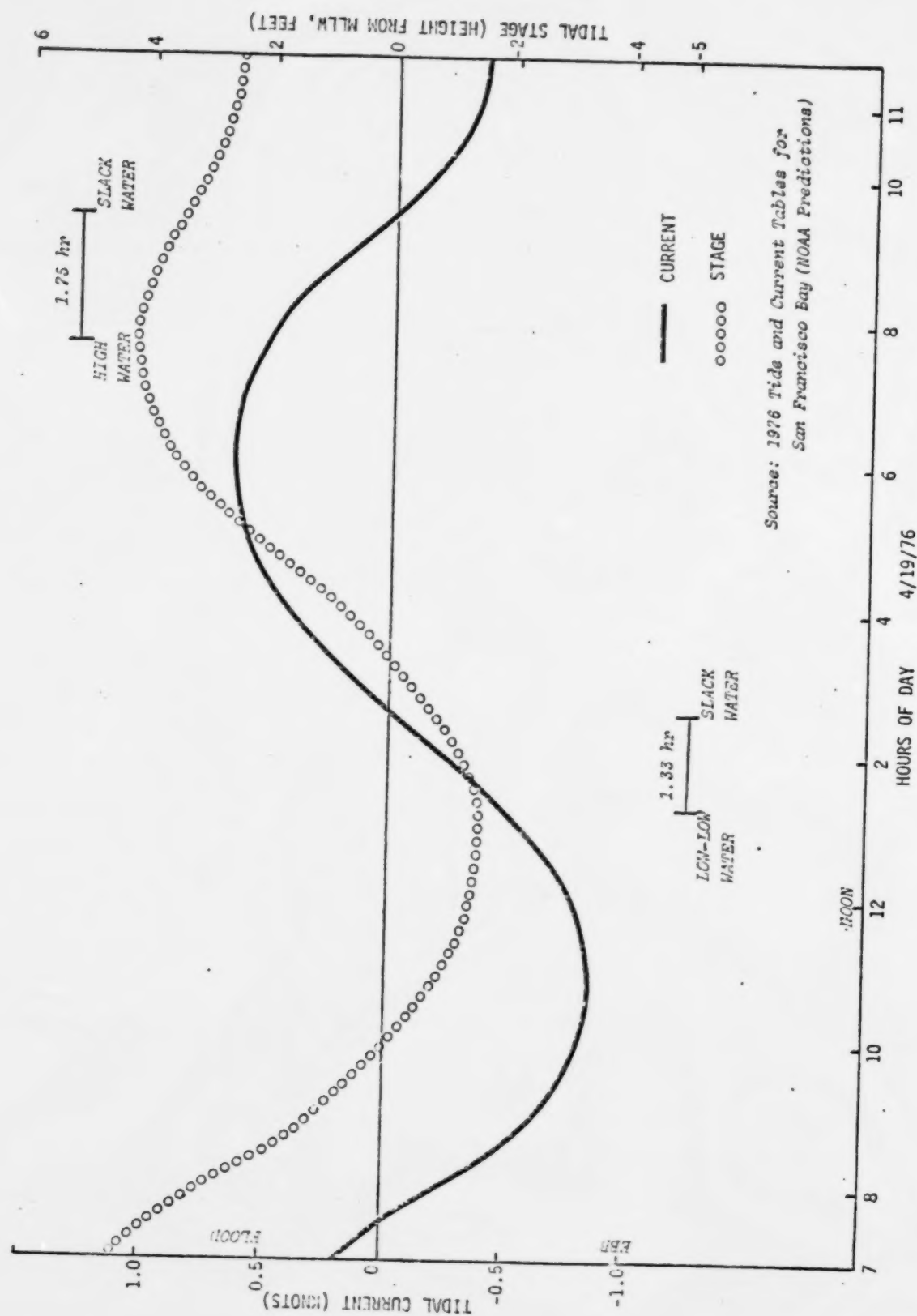


Figure 3-11
PHASE SHIFT OF TIDAL CURRENT AND STAGE
AT SHORE ACRES



POLLUTANTS

INTRODUCTION

Most pollutants and adverse conditions in natural waters can have both subtle, sub-lethal effects on living organisms over the long term as well as dramatic or lethal short-term effects. In most cases, the concentrations of harmful substances causing short-term adverse effects such as death or repulsion of migrating fish are greater than those causing subtle chronic effects. The higher concentrations could be brought about by single incidents such as plant failure or pipeline breakage, or they could result from the buildup of normal loadings of pollutants in the water due to periodically occurring tidal conditions. The pollutants of major concern in this study were four that are known to cause acute toxicity or repulsion to fish: 1) oxygen depression, 2) residual chlorine, 3) ammonia, and 4) heavy metals.

DESCRIPTION AND SIGNIFICANCE OF POLLUTANTS

Biological Oxygen Demand and Dissolved Oxygen Depression

The ambient concentration of dissolved oxygen (DO) is of critical importance to all fish living in and migrating through estuary waters. The DO level can be suddenly lowered from an excess of oxygen-demanding material (BOD) in a municipal effluent discharge, if that discharge is either insufficiently treated or insufficiently diluted by the receiving waters. Since the fish need certain levels of oxygen for survival, a sudden oxygen depression could cause either fish kills or the repulsion, or turning back, of migrating fish if most of the channel cross-section is affected. The time period required for exertion of BOD is usually several days.

Residual Chlorine

Dissolved chlorine is toxic to life. While it is

used beneficially as a disinfectant to kill bacteria and viruses in municipal waste, it can also kill fish and other aquatic life if a high residue of chlorine in treated effluent is discharged into estuary waters. This can happen in the event of a treatment plant de-chlorination failure or malfunction, or even with normal discharge in the absence of dechlorination, and could result in either fish death or repulsion of migration if most of the channel cross-section is affected. Residual chlorine is a major component of the bioassay known as the "toxicity" test.

Ammonia

Ammonia is toxic to most animal life. Ammonia (NH_3) dissolves in water to form ammonium ion (NH_4^+) and ammonium hydroxide (NH_4OH); the latter can cause suffocation through inhibiting the oxygen uptake of hemoglobin. Ammonia becomes more toxic at high pH, low acidity. While ammonia is a natural waste given off in small amounts by fish themselves, it is normally rapidly converted by natural bacterial populations into nitrates and used up by aquatic plants. However, elevated, harmful levels of ammonia could result at a municipal discharge site if large amounts of effluent, containing the ammonia from human waste, were allowed to build up due to river conditions or treatment plant failure. Fish kills or repulsion of migrations could result if most of the channel cross-section is affected by critical ammonia concentrations. However, a critical ammonia concentration cannot be specified clearly, since the toxicity of a given level of NH_4OH is heightened by unpredictable factors in the receiving waters such as heat, acidity, and the presence of other chemical compounds.

Heavy Metals

Trace quantities of many metals, including those of concern in this study (lead, mercury, cadmium, copper, chromium, zinc), are found naturally in most waters; in fact some amounts are necessary for proper growth of many aquatic organisms. Most heavy metals, however, are also toxic to fish and other animals'

nervous systems or circulatory systems even in quite low concentrations and in certain chemical forms. While municipal effluent does not have as many heavy metals as most industrial effluents, a buildup in the river of inadequately treated municipal effluent could possibly bring about toxic or repulsive levels of some of the heavy metals.

Maximum Acceptable Receiving Water Levels

Table 4-1, a compilation of water quality objectives for each pollutant, indicates the levels which, if exceeded, are considered dangerous or undesirable for fish, or for human consumption where fish standards were unavailable.

BACKGROUND WATER QUALITY

Explanation of Tables

Study area estuary waters are being continuously monitored for several water quality parameters by the U. S. Bureau of Reclamation (USBR) in its Delta-Suisun Bay Surveillance Program. The following tables (Table 4-2) present 1972-1974 data from this program; this data spans both a relatively dry year (1972) and a relatively wet year (1974), giving rise to great variability in some data such as that for chlorides.

In addition, the data for heavy metals is qualified by small sample size and unprecise measurement. Many of the data in USBR's printed computer output were coded as "known to be greater (or less) than recorded value." Nevertheless, all data has been presented here for the purposes of completeness and general comparison with concentrations achieved with worst and average case effluent dilutions.

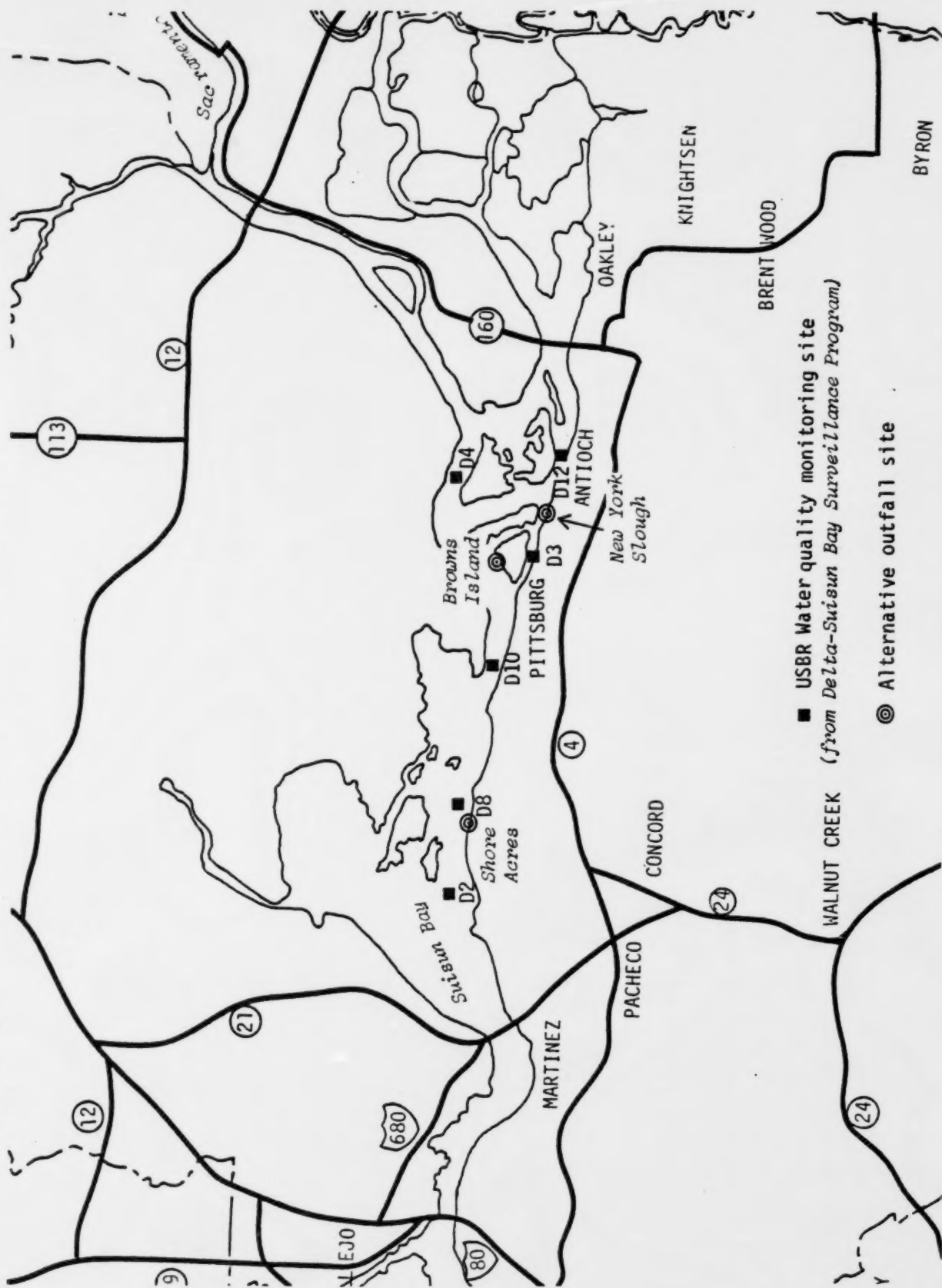
Biological oxygen demand data for Study Area waters are not available through the Surveillance Program; however, dissolved oxygen (DO) was measured,

but is not presented here since DO levels are uniformly high, near saturation, throughout the North Bay and Confluence area (see Basin 2 Plan, p. 14-9).

Table 4-1
PRELIMINARY WATER QUALITY OBJECTIVES

CONSTITUENT OR PROPERTY	OBJECTIVES	SOURCE
1. Dissolved oxygen	85% of saturation or 7.0 mg/l minimum	Basin 2 Plan, p. 4-14
2. Chlorine residual	no Basin Plan standard	
3. Ammonia (NH ₃ -N)	0.025 mg/l as N - for un-ionized form (NH ₄ OH) -05 mg/l 1/20 of the 96-hr TL _m	Basin 2 Plan, p. 4-19 1970 WHO drinking water std. Nat'l Tech. Advisory Comm. 1968 WQ Crit.
4. Heavy Metals	(not to be exceeded more than 10% of the time)	Basin 2 Plan, p. 4-6 (Based on State Board Management Memo 20.)
Cadmium	0.01 mg/l	
Chromium	0.05	
Copper	1.0	These criteria are for municipal use.
Lead	0.05	
Mercury	0.005	
Zinc	5.0	
All: Zone of passage for migratory fish	75% of the cross-sectional area of the waterway	Basin 2 Plan, p. 4-5

Figure 4-1 STUDY AREA USBR WATER QUALITY MONITORING SITES



■ USBR Water quality monitoring site
(from Delta-Suisun Bay Surveillance Program)

◎ Alternative outfall site

Table 4-2
BACKGROUND WATER QUALITY

STATION	Water Temperature ($^{\circ}\text{C}$)		SD%	STATION	Ammonia ($\text{mg/l NH}_3\text{-N}$)		SD%
	MEAN	RANGE			MEAN	RANGE	
D2	13	6-20	30	D2	.05	.02 - .10	40
	19	13-23	12		.05	.02 - .13	60
D8	14	7-21	29	D8	.04	.02 - .07	50
	20	14-23	13		.04	.01 - .09	50
D10	13	6-18	31	D10	.05	.03 - .11	60
	21	17-24	12		.04	.01 - .09	75
D3	16	10-21	23	D3	.05	.05 - .06	20
	20	13-23	11		.06	.03 - .09	50
D4	14	9-20	26	D4	.04	.02 - .07	50
	20	13-23	11		.05	.01 - .09	40
D12	14	6-21	33	D12	.04	.01 - .11	75
	21	13-25	11		.04	.01 - .07	50

STATION	Chloride (mg/l Cl ⁻)			STATION	Cadmium (µg/l Cd)		
	MEAN	RANGE	SD%		MEAN	RANGE	SD%
D2	1211 3596	9-4860 528-7670	115 57	D2	8 46	0-10 10-140	49 123
D8	613 1730	8-4180 127-5020	187 84	D8	- -	- -	- -
D10	343 1258	8-2340 53-3470	193 87	D10	9 33	0-10 10-100	44 120
D3	328 774	30-1300 140-1920	167 78	D3	10 10	10-10 10-10	0 0
D4	72 414	7-740 11-1700	247 131	D4	8 10	0-10 10-10	67 0
D12	79 375	8-695 16-1130	211 101	D12	7 10	0-10 10-20	85 0

KEY: SD% is standard deviation as % of the mean. N is sample size. See Fig. 4-2 for station locations.
Bold face = average winter levels *Italic* = average summer levels

Copper ($\mu\text{g/l Cu}$)

STATION	MEAN	RANGE	SD%	N	STATION	MEAN	RANGE	SD%	N
D2	37 78	10-50 10-180	56 84	6 5	D2	20 95	0-60 10-350	117 179	5 4
D8	- -	- -	- -	0 0	D8	- -	- -	- -	0 0
D10	37 57	10-50 10-120	56 70	6 7	D10	8 10	0-10 10-10	56 0	5 4
D3	50 60	50-50 60-30	0 0	3 1	D3	10 10	0-10 10-10	0 0	2 1
D4	23 30	10-50 10-50	100 93	3 2	D4	8 10	0-10 10-10	67 0	4 2
D12	23 30	10-50 10-50	100 93	3 2	D12	7 10	0-10 10-10	85 0	3 2

Chromium ($\mu\text{g/l Cr}^{+6}$)

STATION	MEAN	RANGE	SD%	N	STATION	MEAN	RANGE	SD%	N
D2	10 ^a 10	10-10 10-10	0 0	5 4	D2	22 44	20-50 10-100	74 84	6 5
D8	- -	- -	- -	0 0	D8	- -	- -	- -	0 0
D10	10 10	10-10 10-10	0 0	5 6	D10	18 34	10-50 10-100	87 101	6 7
D3	10 10	10-10 10-10	0 0	3 1	D3	10 100	10-10 100-100	0 0	3 1
D4	15 10	10-20 10-10	47 0	2 1	D4	40 37	20-50 10-50	43 63	3 2
D12	10 10	10-10 10-10	0 0	2 1	D12	27 30	10-50 10-50	75 93	3 2

a. All readings of $10\mu\text{g/l}$ reported here were recorded as 10k by the USBR study, signifying "actual value known to be less than given value."

The Delta-Suisun Bay Surveillance Program (USBR) does not monitor background mercury levels.

RECEIVING WATER BIOTA - FINFISH

BACKGROUND

A list of the various fish using the North Bay-Western Delta estuary waters is found in Table 5-1; a short-form tabulation from several sources (listed) of their habitats, behaviors, and environmental needs has been compiled into Table 5-2 and represents the major and most relevant facts extracted. Since there are so many species of fish using Delta waters, and since requirements of resident fishes related to water development are generally less demanding than those of anadromous species, (Periph. Canal DEIR, p. IV-80) this study will concentrate primarily upon the sensitivities of the several important migratory fish, as well as of the two rare species.

A graphic representation of the various seasonal fish migrations past the proposed alternative outfall sites is included as Figure 5-1. It should be noted that although the migrations past the Shore Acres site farther to the west are not shown, they would be the same as those shown for Browns Island, since both of these sites are in the main channel of the Sacramento River below the Confluence, and both experience the maximal finfish utilization.

A typical and important food web involving a migratory fish (Striped Bass) is diagrammed in Figure 5-2. All participants in this web are to be found in the vicinity of each alternative outfall site. Although plankton and other invertebrates can suffer short-term damage on long-term deterioration from pollutant excess, this study will focus only on acute adverse impacts in each outfall vicinity to which the higher organisms (Striped Bass, for example) are susceptible.

Table 5-1
LIST OF FINFISH USING STUDY AREA ESTUARY WATERS

COMMON NAME	Introduced Native		Introduced Exotic		Native	
	Anadromous Gamefish	Resident Gamefish	Anadromous Gamefish	Resident Gamefish	Anadromous Gamefish	Resident Gamefish
Striped Bass	X					
American Shad	X					
Chinook (King) Salmon		X				
Steelhead Trout		X				
White Sturgeon		X				
Green Sturgeon		X				
White Catfish			X			
Black Crappie			X			
Black Bullhead			X			
Brown Bullhead			X			
Channel Catfish			X			
Largemouth Bass			X			
Bluegill			X			
Sacramento Perch (BARE)				X		
Garp					X	
Threadfin Shad					X	
Smelt (2 spp.)						X
Starry Flounder						X
Tule Perch						X
Sculpin (2 spp.)						X
Splittail						X
Sacramento Squawfish						X
Sacramento Hiteh						X
Sacramento Blackfish						X
Thicktail Club (BARE)						X

Table 5-2 FISH BIOLOGY SUMMARY

Species

STRIPED BASS
(*Morone saxatilis*)

Significance

Sport fishery worth over \$75 million/yr.
Commercial fishery halted in 1935.

Sensitivities

Spawning needs temperatures from 58° to 68°F.
Salinities of 350 ppm total dissolved solids stop migration;
Spawning is also preferred at under 200 ppm total dissolved solids, although eggs will survive up to 1000 ppm total dissolved solids.
Larvae cannot tolerate temperatures over 73°F.
63°F is upper limit of optimum range.
Survival of juveniles closely related to Delta outflow and amount of Delta diversions.
Survival of young and juveniles sensitive to population levels of *Neomysis*.

General Biology

Feed in salt water; spawn in fresh water.
Adults move downstream during summer and fall.
Spend winter in bays, return to Delta in spring.
Many adults go up Sacramento to spawn; lesser numbers go up San Joaquin to spawn.
Eggs suspended in even slightly moving water; drift with current.
Young concentrated near bottom and along shore, come up somewhat during flood-tide.
Larvae drift with currents but stay near bottom; travel at approximately 1/2 the rate of the river.
No sharp stratification of larvae.
Soon start eating *Neomysis* in Delta, zooplankton in Delta sloughs.
Gradually start eating small fish: threadfin shad.
Adult fish eat primarily a variety of smaller fish, like young salmon.
Adults found near surface.

Specific Biology

San Joaquin river from Antioch eastward to Venice

Island major spawning area. (Spawn in late April-late May).
Over half of spawning done in Sacramento River upstream from the Delta (late May-mid-June).
Eggs drift downstream in Sacramento; move back and forth with slight net downstream movement in San Joaquin.
First summer of most young spent within few miles of the confluence depending on extent of ocean water incursion (young stay at salinity front).
Juvenile pop. (from end of first summer to about 2½-3 yrs. old), concentrates from Martinez to Pittsburg, especially spends time in Suisun Bay.
Port Chicago-Collinsville the "main nursery area" for larvae.

Species

KING (CHINOOK) SALMON

(*Oncorhynchus tshawytscha*)

Significance

Supply 75% of commercial catch in ocean; worth \$25 million/yr.
Important inland sport fishery but not as important as ocean fishery since catch of this species is restricted, to protect the small (declining) population.

Sensitivities

Both adults and juveniles need positive (downstream) outflow.
Adults need gradual salinity gradient for migration; young need it to adjust to sea habitat.
Estuary must have homesteam water in it.
Need high DO; migration stopped when DO < 5 ppm and temperature > 70°F, for both adults and juveniles.
Fingerlings and adults and juveniles prefer temperature of 66°F and below.
Eggs need 45°F to 55°F and below.

Delay of migration in lower Sacramento confluence area may hamper spawning since fish and eggs are maturing rapidly and are still far from spawning grounds in the north.

General Biology

3 "runs" (migrations upriver to spawn):

- 1) Fall. Largest river spawning is in upstream Sacramento River. Spawning is between October & January in tributaries, and between October and March in Sacramento River. Man-made hatcheries help.
- 2) Winter. Spawning only in main stem of Sacramento River; spawning takes place in May and June. "Run" through Delta is in late fall/December.
- 3) Spring. Run moves through Delta in late winter/early spring.

Least numerous run.

Spawning time is late October;

Occurs in main stem Sacramento River near Redding.

Young's food are *Neomysis*, *Corophium*, and insects. After hatching, juveniles drift downstream; some are moving down the Sacramento river during every month of year; however, most down migrate in May (April-June).

Adults die after spawning.

Juveniles prefer top two meters during day; evenly distributed at night; also prefer faster currents and major flow channels.

Specific Biology

San Joaquin can support only a fall run. Spawning takes place not in San Joaquin river but further north and east in the Sierra stream tributaries (Mokelumne, Tuolumne, Stanislaus, Merced). (San Joaquin River can't support runs often because of reverse flow and no homesteam water, plus DO levels often are depressed, <2 ppm near Stockton.) Sacramento River is a nursery for young as they drift down. Heavy runs (upstream) have been observed past PG&E Contra Costa plant from September-December.

Species

STEELHEAD (RAINBOW) TROUT
(*Salmo gairdnerii*).

Significance

Important fresh water sport fishery in upstream Sacramento, American, Feather and Mokelumne Rivers, although smaller catches than those recorded for king salmon or striped bass.

Sensitivities

Similar to king salmon for temperature and water quality.
Optimum temperature 68°F.
Absolute lethal temperature 82°F.
Order of metal salt toxicity:

Mortality occurs at:

Hg

Ag

Cu

Pb - 0.12 -0.36 ppm in hard water

0.006-0.012 ppm in soft water

Zn

General Biology

Move upstream through Delta in August through winter; peak in mid-October on the Sacramento.

Spawn in late winter/February.

Artificial hatcheries help.

Young migrate downstream winter/early spring (January-March).

Those adults which don't die after spawning move downstream in March-April.

Juveniles remain in near spawning area for first year till migrate out.

Species

AMERICAN SHAD
(*Alosa sapidissima*)

Significance

Very numerous. Important sport fishery in upper Sacramento, middle Sacramento and in Delta.

Sensitivities

Spawn in temperature from 58°F to 70°F.
Otherwise little is known of their requirements.

General Biology

Adults in Sacramento spring spawning run get into Delta starting February, peak in numbers in May. As migrating, feed on *Neomysis* plus some zooplankton. Most adults die after spawning but not all. They migrate out in a weak condition during summer. Spawning occurs from April - July, peaks in late May and early June. Spawning occurs in upper Sacramento and tributaries. Eggs settle to the bottom, some carried downstream. Out migration time is long; some young leave right after hatching, while others stay near spawning grounds till 2-3 inches long. Larvae and juveniles in river system in May & June, older juveniles in July-November. July and August are peak outmigrating months. Outmigrating young seek slower currents; eat zooplankton.

Specific Biology

Adults head for Sacramento River above Sacramento, and into tributary streams. Very few shad spawn in Delta or in San Joaquin River. Outmigrating shad mostly in Mokelumne and Sacramento mainstem, but found also in south Delta and lower San Joaquin river. July-December outmigrating young found in N. Bay/ W. Delta in slower moving portions of channel.

Species

WHITE STURGEON & GREEN STURGEON

(*Acipenser transmontanus* & *A. medirostris*)

Significance

White sturgeon very numerous; green sturgeon has small population. Important and fast growing sport fishery but not as large as bass, salmon, etc.

Sensitivities

Spawning in temperatures of 46°F - 72°F. Adults can take high salinities, found in San Pablo Bay where salinities range from 6000 to 16,000 ppm TDS. Juveniles need large populations of *Neomysis* & *Corophium*.

General Biology

Early spring upstream migration to spawn. Spawn in March-June. Adults move downstream after spawning in late spring (do not die). Larvae migrate downstream on near bottom; eat *Neomysis* & *Corophium*. Adults eat benthic invertebrates and small fish.

Specific Biology

Found in San Pablo Bay and Suisun Bay in fall & winter; in lower Sacramento around Collinsville in late winter. Migrate up the Sacramento River in early spring. Spawn in upper Sacramento River, not in San Joaquin River system-although adults caught in upper San Joaquin river in spring. Young and juveniles inhabit Delta & Suisun Bay (summer).

Species

RESIDENT GAME FISHES (Catfish & Sunfish)

Significance

Support a popular sport fishery, especially white catfish, and (important but not as intensive) black crappie, large-mouth bass, bluegill.

Sensitivities

Need quiet waters; prefer salinities of <1000 ppm TDS.

Catfish

Spawn in 70° water or over.

Can take salinities of 4-5000 ppm TDS.

Sunfish

Spawn in 60° - 80°F water

General Biology

Tend to be small.

Catfish

Spawn late spring, early summer in quiet areas; eggs in nest on bottom.

Omnivorous, most sizes eat *Corophium*, *Neomysis*, midge flies and fishes.

Sunfish

Spawn in quiet areas.

Eat *Neomysis*, *Corophium*, crayfish, small fish.

Specific Biology

Mostly found in quiet sloughs off Delta channels and on flooded islands.
Generally non-migratory.
Young feed in dead-end sloughs.

Species

Non-game fishes

1. Smelt
2. Starry Flounder
3. Threadfish shad
4. Splittail (Minnow)
5. Northern Anchovy

Significance

All: Food for larger fish.

1. Very numerous
2. Very numerous
3. Very numerous; major food of striped bass and other game fish.
4. Native to Delta; common but has a limited distribution.
5. Food for striped bass.

Sensitivities

Tolerant of salinity since adults found in San Pablo Bay.

General Biology

1. Remain near surface; migrate farther upstream in spring to spawn.
2. Bay's population represents the young of marine fish feeding upstream.
5. Abundant in spring while spawning in N. Bay waters.

Specific Biology

1. Found throughout Suisun Bay to W. Delta main channels.
2. Found throughout W. Delta area.
3. Mostly found in E. Delta but occur all through W. Delta/R. Bay area.
4. Found throughout area - Suisun Bay to Delta.
5. Abundant in Suisun Bay in summer.

Species

Thicktail chub

Significance

Rare & endangered species:
"Uncertain status" - Bureau of Sport Fisheries, 1973.
"Endangered" - Cal. Dept. of Fish & Game, 1974.
"Fully Protected" - Cal. Dept. of Fish & Game, 1971.

Sensitivities

Basin 2 plan (p. 11-38) indicates that it is "likely to be affected by changes in water quality or quantity and (is) restricted in (its) area distribution."

Species

OPOSSUM SHRIMP
(*Neomysis mercedis*)

Significance

Principal food for young of striped bass, and other game fish.

Sensitivities

Sensitive to abrupt salinity increases and high temperatures, but more so to salinity than temperature.
Like temperatures of 60 - 72°F but can't take >72°F.

General Biology

Migrates with salinity front.
Eats detritus and phytoplankton.
Population peaks from June - August.

Specific Biology

Population is located in river reach from Port Chicago in Suisun Bay to Rio Vista and to Antioch.

Species

CLADOCERANS, COPEPODS, & *Corophium*

Significance

Food for young of American Shad and White Sturgeon, and other game fish.

General Biology

Bottom-crawlers.

Specific Biology

Concentrated in Port Chicago-Chippis Island-Collinsville river reach during June when young fish are migrating down through the area.

Figure 5 -1 FISH MIGRATION PATTERNS

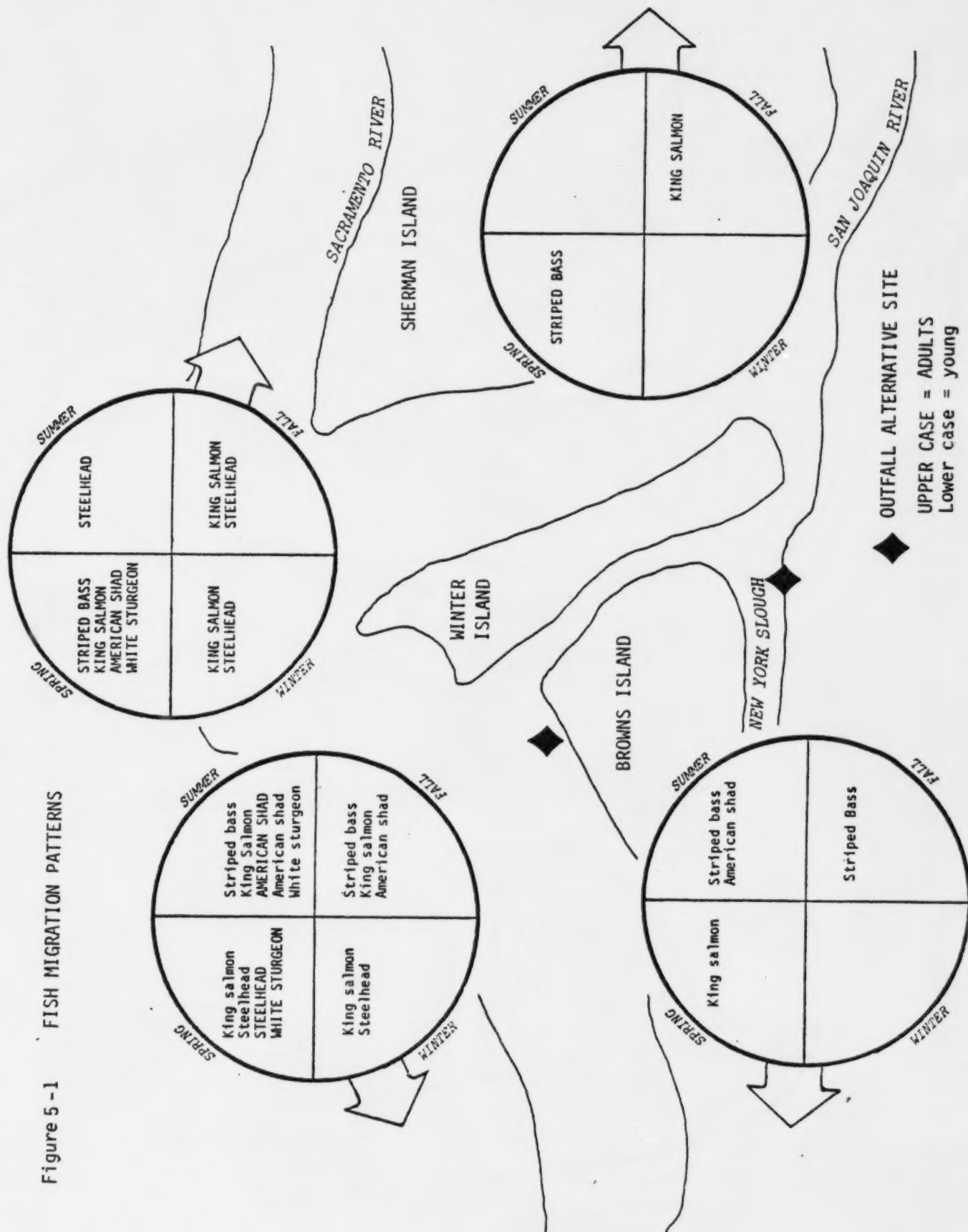
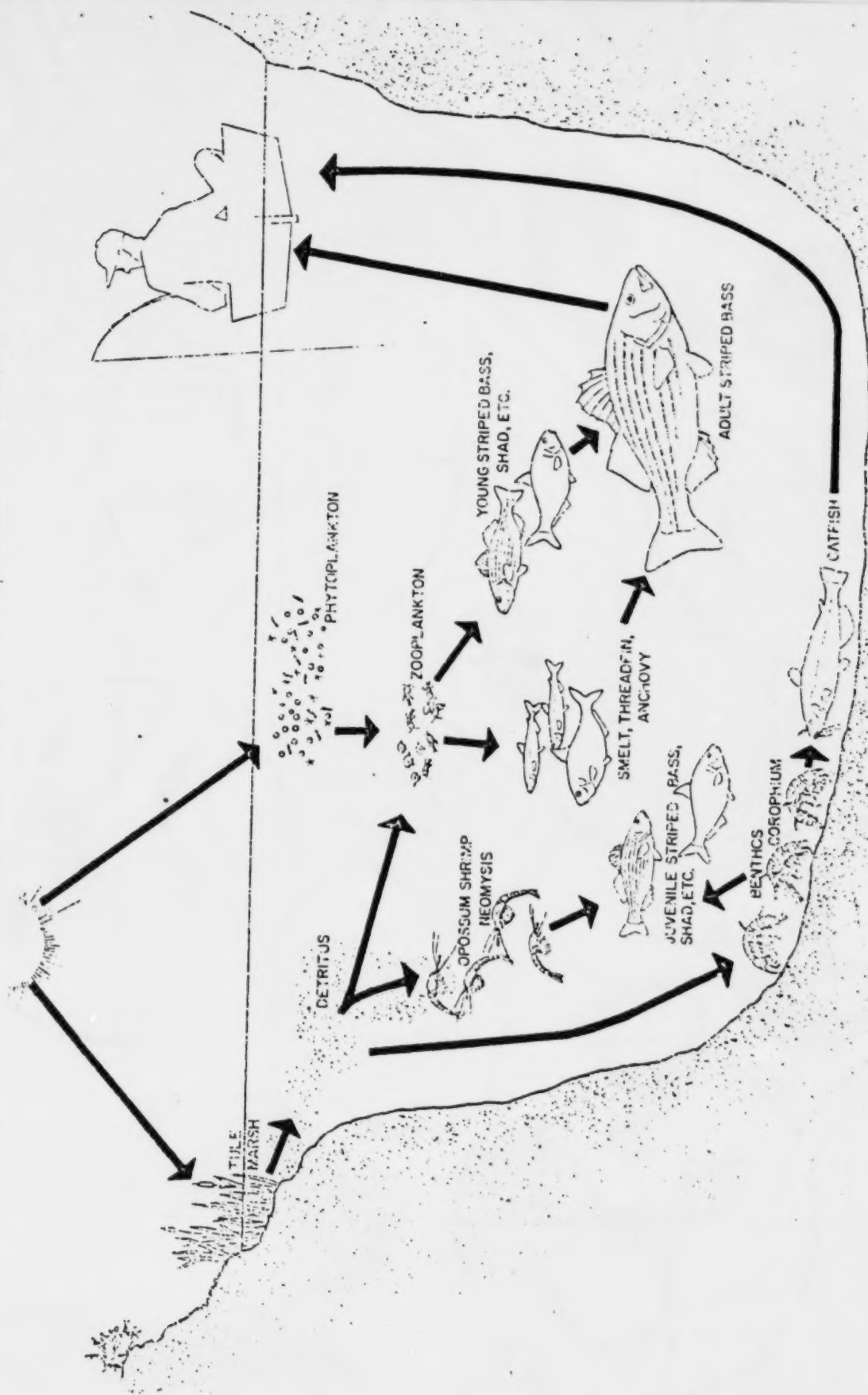


Figure 5-2 ENERGY-FOOD RELATIONSHIPS FOR STRIPED BASS IN THE DELTA



taken from Arthur D. Little, Brown & Caldwell Consulting Engineers, San Francisco Bay-Central Valley Regional Assessment Study (1975), Figure III-8.

IMPACT OF DISCHARGE ALTERNATIVES

DEFINITION OF WORST CASE/AVERAGE CASE

Pollutant concentration and duration of exposure determine the acute biological impact of wastewater discharge to surface waters. The analysis of outfall alternatives emphasizes the "worst case" in order to provide a reference point for impact assessment. If the worst case is generally acceptable, then normal operation will be acceptable; if the worst case is not acceptable, then the disparity indicates the degree of mitigating effort that will be necessary. Table 6-1 defines the worst and average cases.

TABLE 6-1
DEFINITION OF WORST CASE CONDITIONS

PARAMETER	WORST CASE	AVERAGE CASE
Peak Tidal Cycle Current at Golden Gate	*1.9 knots	*3.0 knots
Net River Outflow	4500 cfs	27,000 cfs
Delta withdrawal	5000 cfs	3,600 cfs
Salinity	---- 6ppt ----	
Wastewater Discharge	*26 MGD (40 cfs)	*13 MGD (20 cfs)

* Denotes major factor
1 knot= one nautical mile/hour=100 feet/min.
cfs= cubic feet/second
MGD= million gallons/day = 1.5 cfs

Conditions significantly approaching "worst case" will occur approximately 10 times per year and will last for 3 hours.

As outlined in previous chapters, the least effluent dilution (hence the greatest pollutant concentration) occurs in the vicinity of the outfall during the period of low current comprising "slack water," occurring at the changing of the tide. The magnitude of current below which effluent dilution drops is called the "critical current" and is typically 0.06 knots to 0.15 knots. (One nautical mile is 6000 feet; one knot (kt) is one nautical mile per hour, or 100 feet per minute).

Although river salinity affects the value of critical current, the principal factor determining the magnitude of pollutant accumulation in the immediate vicinity of discharge is the duration of slack water, a function of the tidal cycle. For that reason, the worst case involves a weak tide, one with a low peak current, and hence a long duration of slack.

Current predictions are available for the Golden Gate entrance to the San Francisco Bay Estuary. A weak tidal current at the Golden Gate results in a weak current at each discharge site. The magnitude of the weak current (1.9 knots at the Golden Gate) is expected statistically to occur 10% of the time. This means that one tide in ten will produce a tidal current of this magnitude or smaller. The average current is greater and results in shorter duration of slack water at each site hence reducing the time available for formation of the plume. Although the tidal cycles vary in a complex fashion, the significance of the 10% tide can be approached by considering that there are approximately four periods of slack water during the day. A 10% tide, resulting in a long period of slack water, will occur one time in ten, thus the condition described may be expected once every 2½ days or twelve times per month.

The average case is based on slack times derived from the medium value for peak current, 2.9 kt at the Golden Gate. Conditions will be better

than "average" half the time and worse than average half the time as well.

Seasonal variation in fresh water outflow from the Sacramento and San Joaquin Rivers affects ambient salinity. The critical value of tidal current increases with increasing salinity since the effluent rises more strongly. The effect is small; both the worst case and average case use summer outflow conditions.

Discharge affects the unit pollutant loading of the outfall and is significant under some conditions. The worst case analysis uses the 1996 peak discharge projection of 24 million gallons per day (instantaneous) (MGD) or 40 cubic feet per second (cfs). Average flow will be 12.4 MGD in 1996.

COMPARISON OF DISCHARGE SITES

The three alternative discharge sites are in similar hydraulic environments: The diffuser is at a depth of 20 feet; each location experiences variable salinity due to seasonal and tidal effects; tidal currents dominate the flow at each site. Table 6-2 summarizes the descriptions in Section 3.

Differences between the three sites are several: The parallel orientation of the New York Slough diffuser due to the adjoining ship channel contrasts with the Shore Acres and Browns Island discharges which may use a diffuser perpendicular to the current. The effect of a lower current in the side channel at Shore Acres and the slightly greater mean salinity combine to increase the period of time during the changing of the tides when the current at Shore Acres is small or subcritical as defined earlier. Although none of the outfalls lies near areas of special biological sensitivity, all of the New York Slough discharge and much of Browns Island discharge will be injected into the San Joaquin River and Delta Sloughs by the flood tide. As described in the draft EIS this results in a net accumu-

Table 6-2
HYDRAULIC ENVIRONMENT AT OUTFALL SITES

PARAMETER	NEW YORK SLOUGH	BROWNS ISLAND	SHORE ACRES
Channel			
- Width (Ft)	850	5000	1500
- Maximum Depth (Ft)	30	55	20
- Aspect Ratio (D/W)	0.035	0.010	0.015
- Cross Section (1000 Sf)	25	100	19
- Horizontal/ vertical mixing ratio	3.5	7.0	5
Current			
- Ratio to Golden Gate (multiplier)	0.3	0.3	0.2
- Average Peak (kt)	0.9	0.9	0.6
- 10% Peak (kt)	0.6	0.6	0.4
- Uniformity in Channel	high	high	high
Salinity			
- Winter (ppt)	1	1	1
- Summer	5	5	10

lation of discharge materials roughly 25% greater at the New York Slough and Browns Island locations compared with the Shore Acres discharge location.

Referring to the local impacts of discharge which is the topic of this study, three situations suffice to describe the movement of discharged wastewater. Most important is the accumulation of effluent in a pall during the period of slack water or subcritical flow. Second is the path and subsequent dilution that the pall experiences as the tidal current increases and moves it along the river. Third is the plume of rapidly diluting effluent that trails downstream from the outfall site during the majority of the tidal cycle when the current is above the critical level.

WORST CASE

Pall Formation

During periods of low current, the continuous discharge and diluted wastewater represent a large flux from the diffuser at the bottom of the river to the point where buoyancy and discharge momentum of the diluted wastewater is lost near the surface. Unless there is significant stratification, the terminal point of initial dilution will be at the surface. The discharge will form a blanket roughly 5 feet in thickness which will spread laterally from the point of discharge. Unfortunately, in a shallow river, the clean water required for continuing dilution must come in along the bottom in close proximity to the polluted water spreading away from the discharge along the surface. By considering the interference between efflux and influx it appears that the discharge pall will be drawn to the bottom of the river in the vicinity of the outfall after 10 to 30 minutes of discharge with no ambient current.

Considering the duration of subcritical current or slack water at the three discharge sites, it is

possible to construct a rough model of effluent dilution that constitutes the pall. Table 6-3 compares the dimensions of the pall calculated for the three areas. The degree of error in both environmental

Table 6-3

WORST CASE PALL

PARAMETER	NEW YORK SLOUGH	BROWNS ISLAND	SHORE ACRES
Critical Current (kt)	0.14	0.14	0.18
Duration of Slack (min)	55	55	120
Linear Travel During Slack (A)	200	200	540
Waste Discharge Rate (cfs)	40	40	40
Volume Discharged During Slack (1000 cfs)	132	132	288
Diffuser Orientation to Current	perpendicular parallel parallel		
Diffuser Depth (Ft)	20	20	20
Pall at End of Slack			
Average Dilution	20:1	23:1	22:1
Central Core			
Depth (Ft)	20	20	20
Width (Ft)	120	260	270
Length (Ft)	450	250	500
Average Dilution	16:1	20:1	18:1
Surface Fringe			
Depth (Ft)	5	5	5
Width (Ft)	520	750	780
Length (Ft)	950	720	980
Area (1000 sf)	390	420	600
Average Dilution	26:1	27:1	24:1

parameters (current measurements) and in model construction means that these dimensions are only approximate. The estimates are conservative, i.e., they represent less dilution in principle than is probably achieved in actual practice. Nonetheless, the model provides a means of relative comparison between three points based on the differences in hydrodynamic characteristics described above. It is sufficiently accurate to allow biological assessment, but is not intended as an engineering design analysis.

In each case the resulting pall is shaped somewhat like an underwater mushroom cloud. The portion of discharge which spreads outward during the first half of the slack water period forms a large cap delineating the maximum overall dimensions of the waste field. Dilution at the perimeter of the field as shown is roughly 100:1. Dilution rises abruptly further away from the boundary. The central portion of the pall, representing the stalk of the mushroom, is formed within the latter half of the slack period when it appears that the interference between pollutant efflux and ambient influx becomes sufficiently great to cause re-circulation within the immediate vicinity of the diffuser. This causes the waste field to extend from the surface to the bottom in an area roughly equal to the immediate discharge zone.

The resulting dilution requires a comparison of pall size and wastewater input. See Table 6-3. Browns Island and New York Slough have the same input quantity (50 minutes of discharge), yet the parallel diffuser orientation at New York Slough results in a smaller more compact pall with less dilution. The input discharge at Shore Acres is larger (110 minutes of discharge) which results in a larger pall than is observed at Browns Island, with slightly less dilution. Despite the greater discharge, the perpendicular orientation at Shore Acres still results in slightly greater dilution than calculated for New York Slough.

Pall Dispersal

At the end of the period of slack water, the pall has reached its maximum extent as described in Table 6-3. During such formation, concentrations and dimensions are smaller than those represented by the figures in Table 6-3. When the tidal current rises above the critical level, the pall is shifted away from the diffuser. At this point, dilution in the immediate vicinity of the outfall becomes high. The pall itself is no longer receiving further waste material. Yet it still represents a large mass of waste which must be further dispersed.

As the pall is drawn downstream it is subject to horizontal and vertical mixing. This results in secondary dilution which is a function of the degree of secondary or transverse currents within the river and which increases over time.

As the tidal cycle progresses, the current rises to its peak and falls again to zero over the course of six and one-quarter hours. At the end of a weak tide, the pall created by the last period of slack water has been moved either up or down stream by roughly two and one-half miles and has been subjected to a secondary dilution of 10:1. Coupled with 20:1 dilution achieved within the pall itself, at the end of slack the total waste dilution will be roughly 200:1 or greater. For the purposes of this study, that represents sufficient dilution to obviate acute local or short-term impacts on receiving water biota.

The three sites are compared in figure series 6-1 through 6-9.

The pall for each alternative under worst case conditions is shown on maps which depict the shape and location of the pall from formation to ultimate dilution beyond 100:1 (See Figure 6-1, 2 & 3). The pall shown is that formed during slack water at the end of ebb tide. The smaller circle, to the

Figure 6-1

WORST CASE PATH OF PALL TRANSPORT AT NEW YORK SLOUGH (WITH PEAK EFFLUENT FLOW)

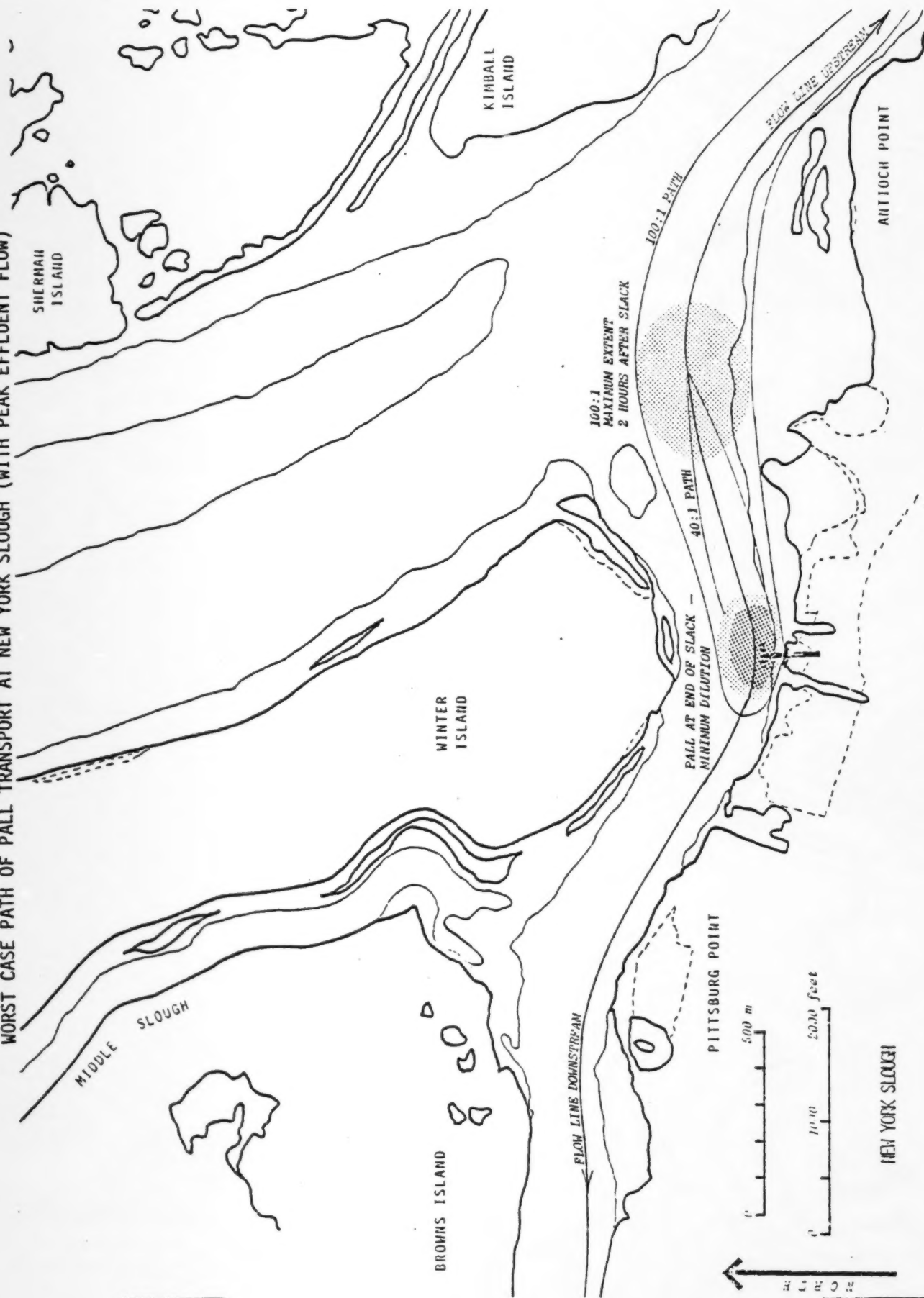


Figure 6-2
 WORST CASE PATH OF PALL TRANSPORT AT BROWNS ISLAND (WITH PEAK EFFLUENT FLOW)

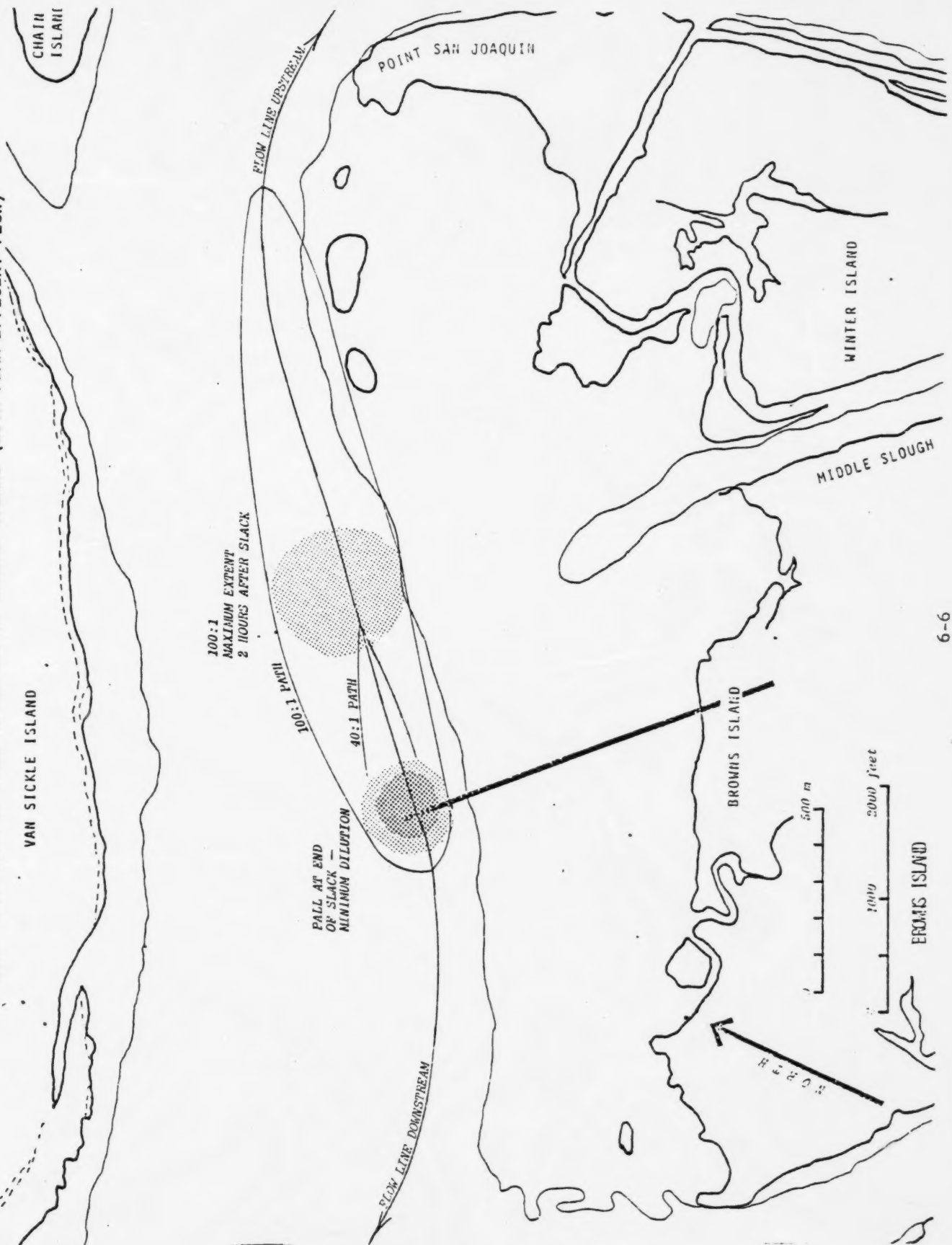
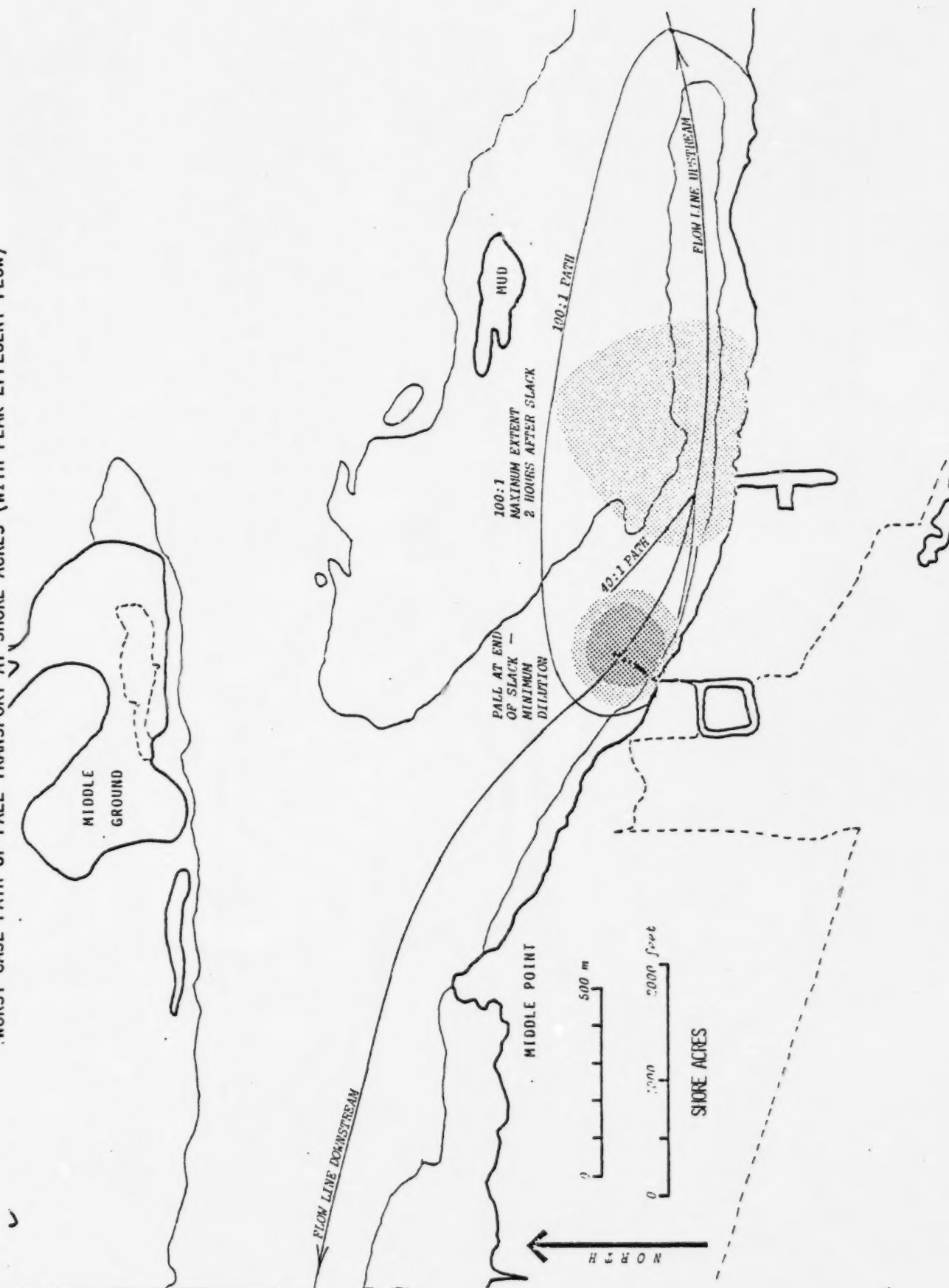


Figure 6-3
 WORST CASE PATH OF PALL TRANSPORT AT SHORE ACRES (WITH PEAK EFFLUENT FLOW)



left, shows the pall at the end of slack. Tidal stage is low water and wastes have accumulated around the diffuser. Two zones of dilution are depicted, 40:1 (dark shade) and 100:1 (light shade). At the end of slack, the zone of 40:1 is large in all cases.

As the tide changes, the flood current becomes stronger, shifting the pall upstream. The secondary dilution acts essentially to transfer waste out of the inner zone of greater concentration (40:1) into the outer zone. This results in a gradual contraction of the 40:1 zone which is depicted on the map as "40:1 path." The area within the 40:1 path indicates the portion of the river which will be exposed to dilution of 40:1 or less as the pall passes over.

Although waste passes out of the 100:1 zone with secondary dilution, the influx from the inner zone over the first few hours results in a net increase in extent for the 100:1 zone. That is shown depicted on the map as the "100:1 path" which first enlarges, then dwindles as further mixing occurs.

The greatest in extent of the 100:1 zone is depicted on the maps by the large, light grey circle on the right, labeled "maximum extent." Comparison of the discharge concentrations with biota sensitivity show that 100:1 dilution is required; the maximum extent corresponds approximately to the maximum potential blockage of the river for the parameters examined.

The transverse extent of the pall is shown in cross-section in Figures 6-4, 5 & 6. The first cross-section for each site (a) is the pall at the end of slack, at the outfall itself. The second cross-section (b) shows the maximum extent of the 100:1 zone.

Plume

When ambient current exceeds the critical value, the discharge jet is pressed against the river bottom, diluted waste is rapidly transported away from the diffuser and lateral spreading is minimal.

During the transition period, dilution increases from the minimum value in the pall at the end of slack as shown in Table 6-4. That initial dilution is achieved within a few hundred feet of the diffuser.

Table 6-4

DILUTION WITH CURRENT

TIME AFTER CURRENT REVERSAL (min)	INITIAL DILUTION			SHORE ACRES
	NEW YORK SLOUGH	BROWNS ISLAND		
15	*23:1 *41:1	*27:1 *48:1		*27:1 48:1
30	*20:1 41:1	*24:1 75:1		*24:1 *45:1
60	24:1 58:1	48:1 145:1		*23:1 96:1
120	30:1 76:1	84:1 250:1		56:1 170:1
180 (peak current)	30:1 90:1	100:1 300:1		67:1 200:1

Bold Face = Worst Case: Weak Tide, Peak Discharge
ITALIC = Average Case

* Denotes Average Dilution within Pall

Figure 6-4 (a)
 WORST CASE PALL—AT OUTFALL
 NEW YORK SLOUGH

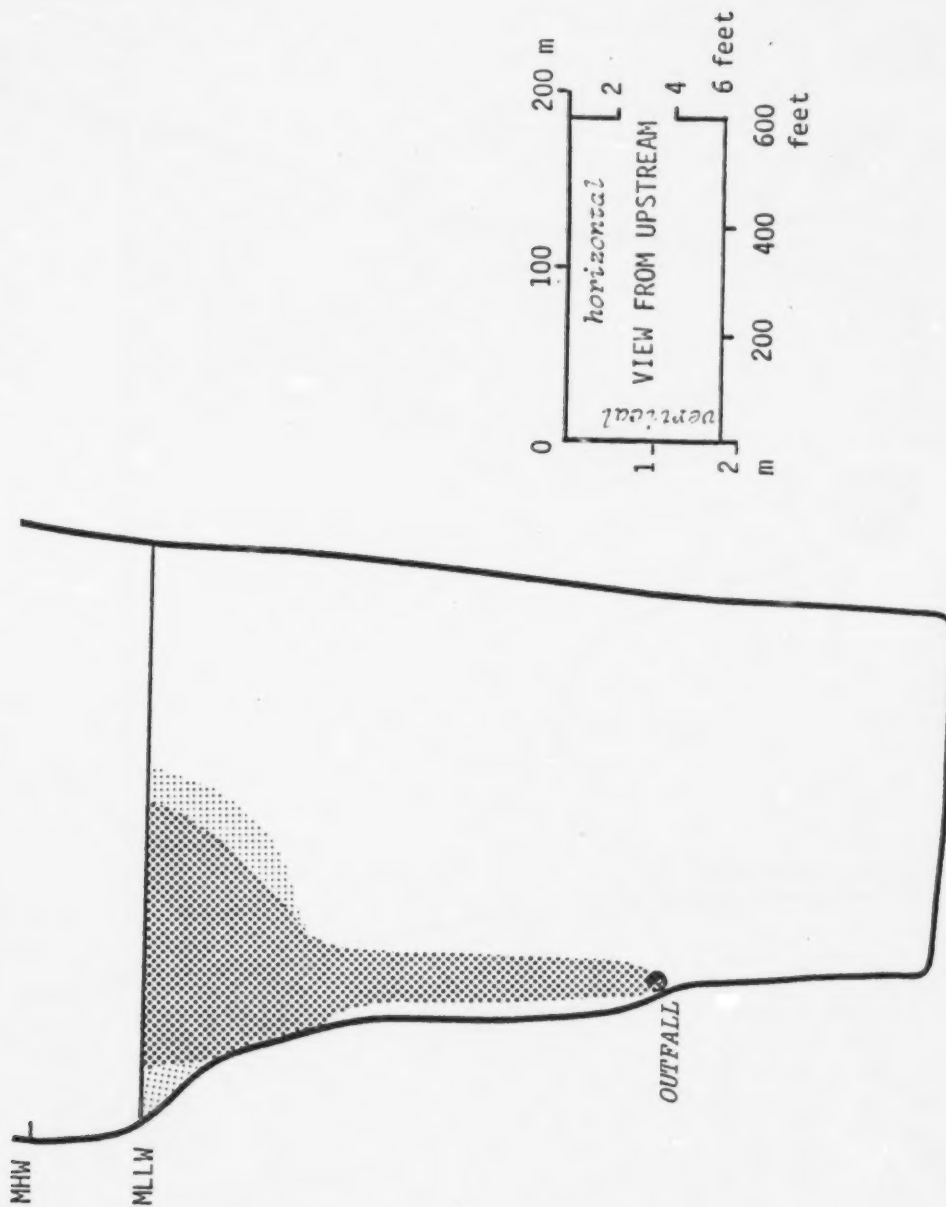


Figure 6-4 (b) WORST CASE - MAXIMUM EXTENT
UPSTREAM FLOODTIDE
NEW YORK SLOUGH

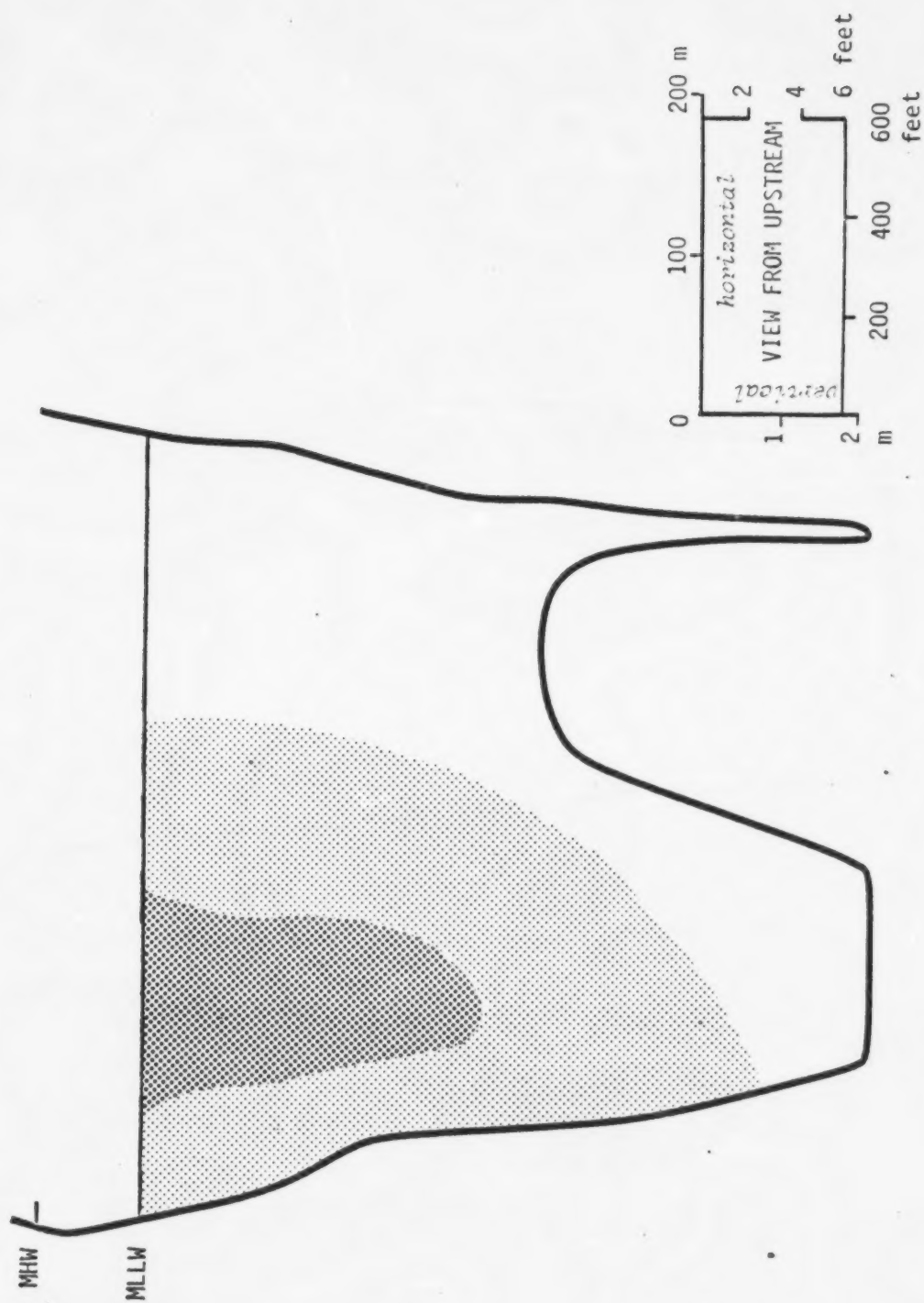


Figure 6-5 (a)
 WORST CASE PALL--AT OUTFALL
 BROWNS ISLAND

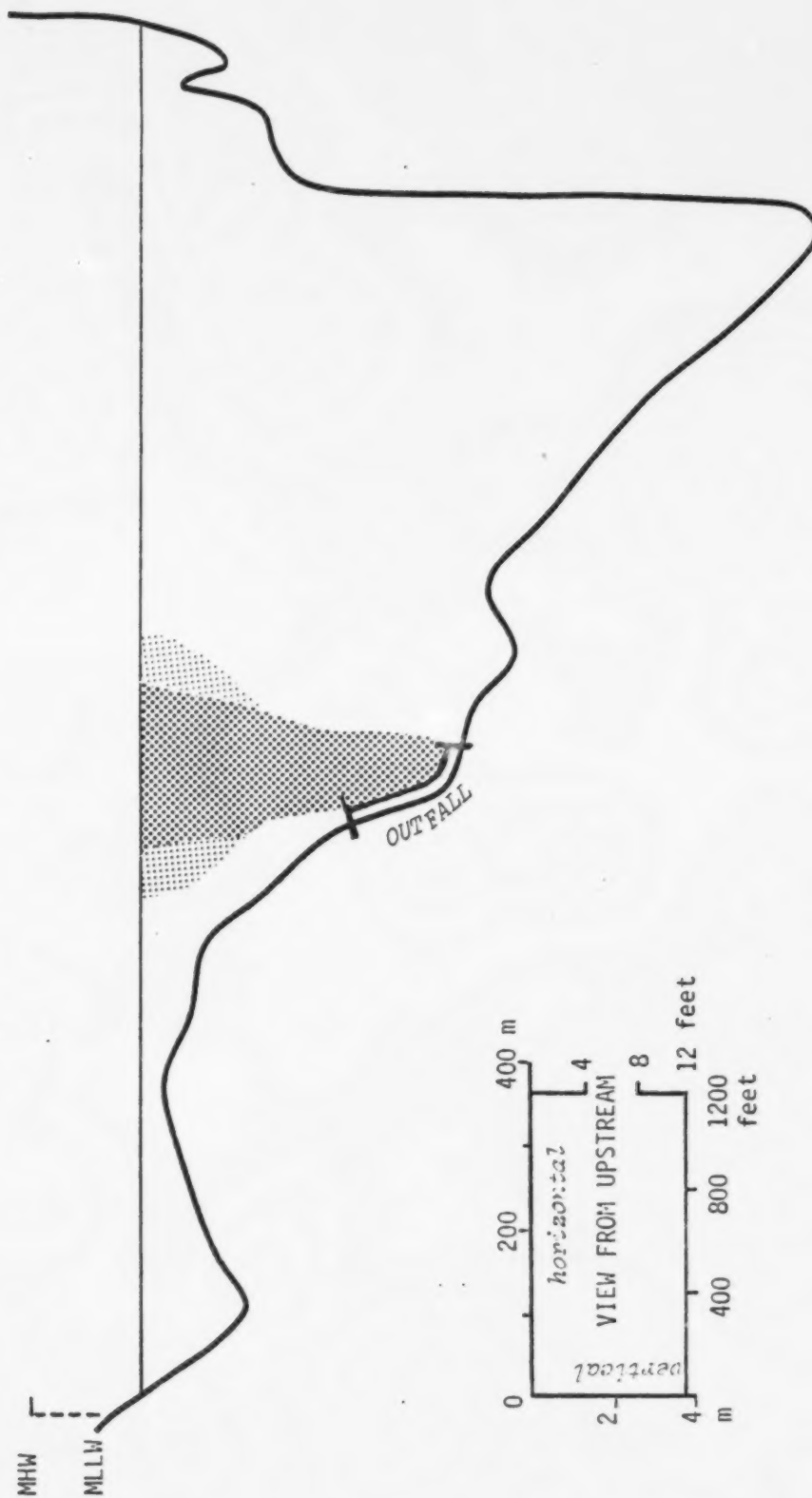


Figure 6-5 (b) WORST CASE — MAXIMUM EXTENT
UPSTREAM FLOODTIDE
BROWNS ISLAND

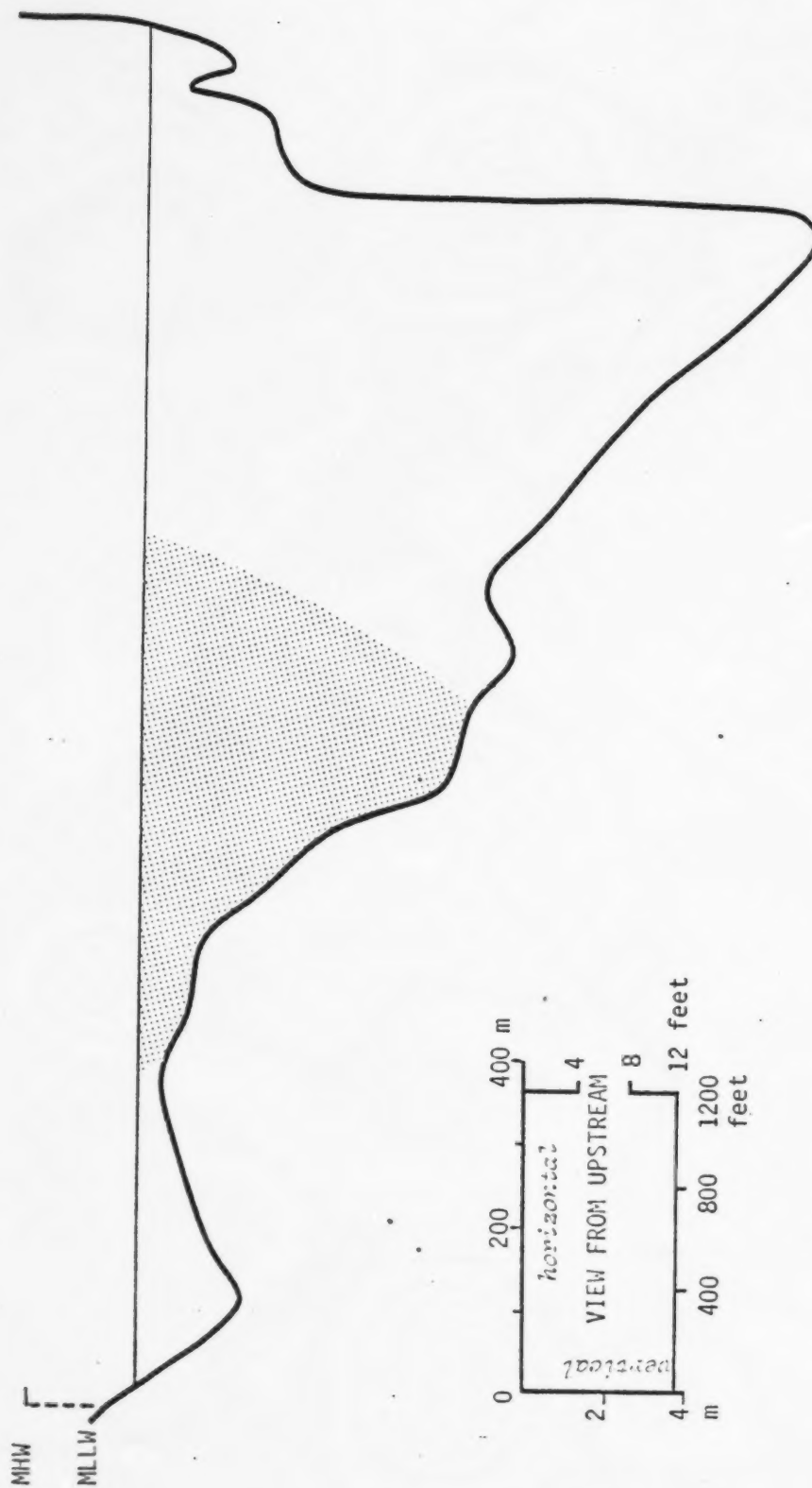


Figure 6-6 (a)
 WORST CASE PALL-AT OUTFALL
 SHORE ACRES

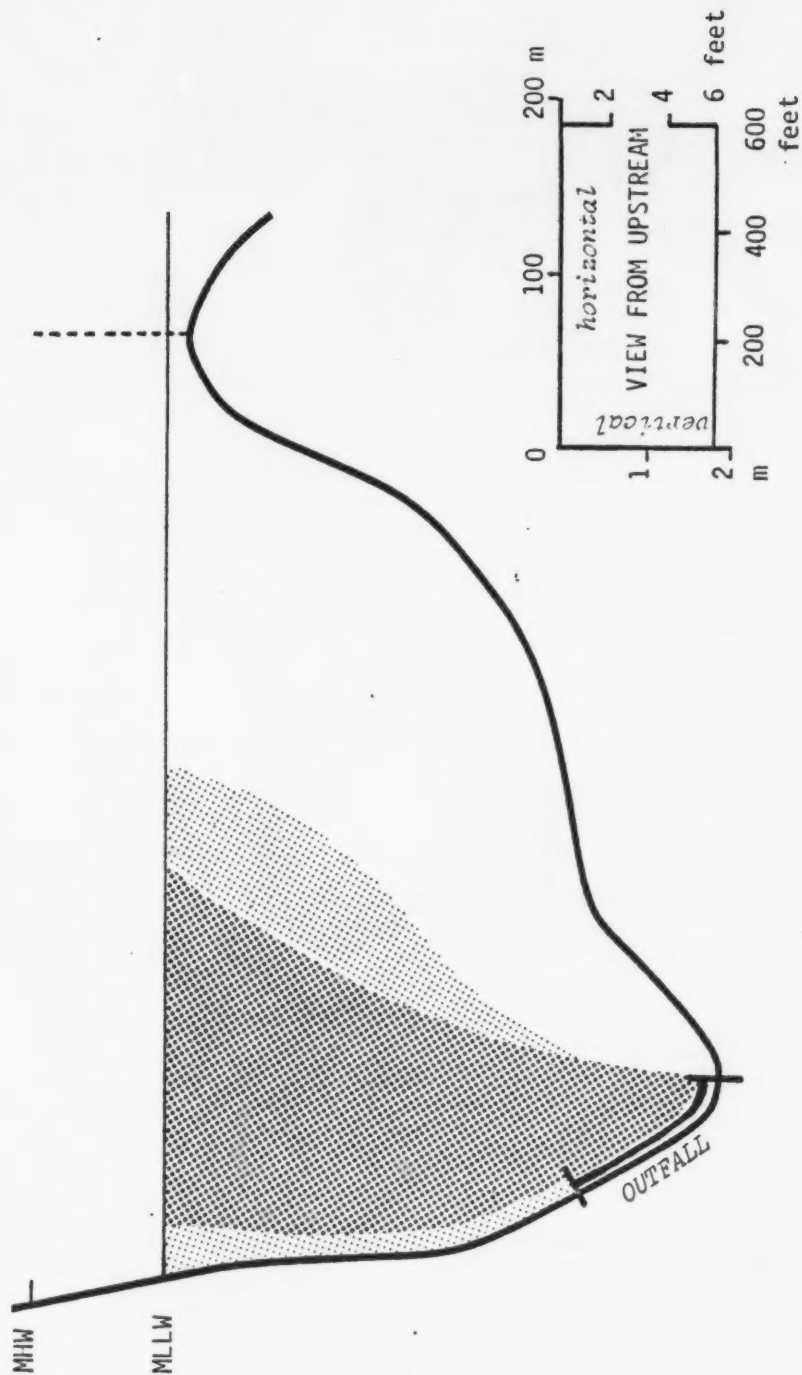
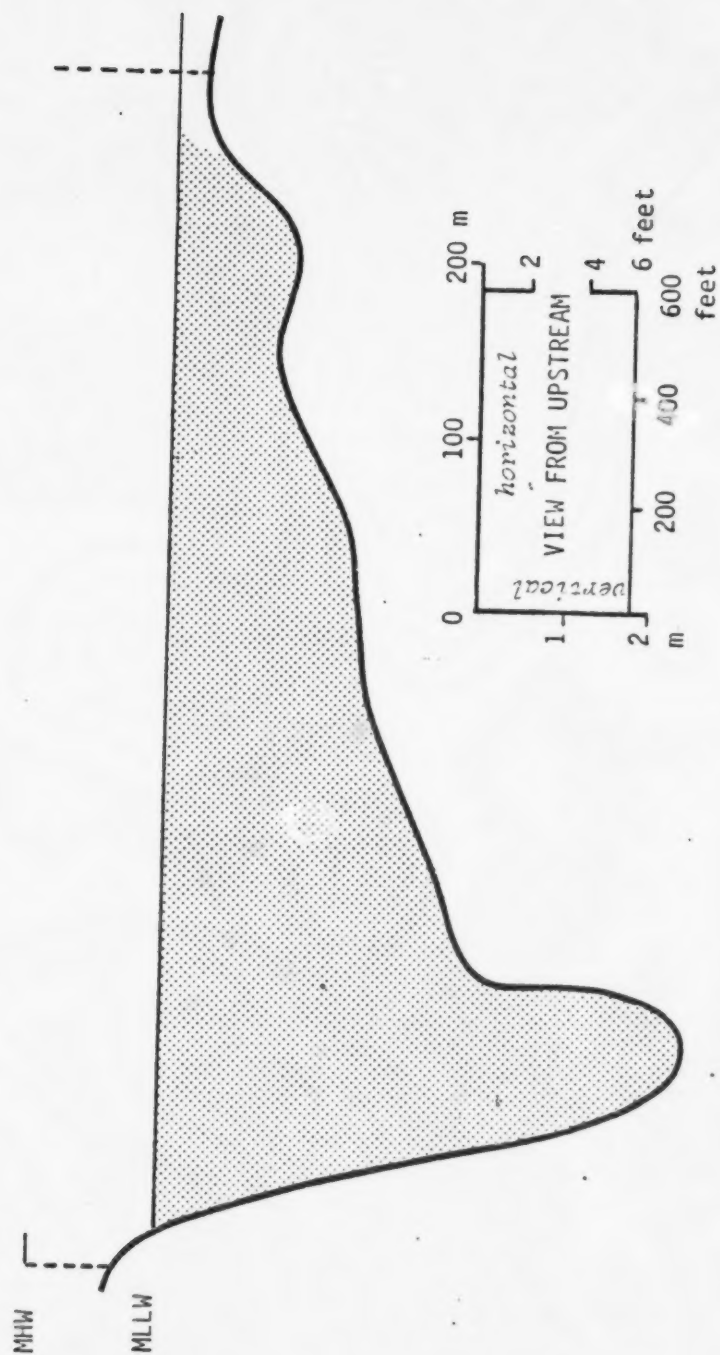


Figure 6-6 (b) WORST CASE MAXIMUM EXTENT
UPSTREAM FLOODTIDE
SHORE ACRES



The major factor in dilution with high current is the ratio of river flux to effluent flux. River flux is determined by current velocity and by the length of diffuser perpendicular to the current.

Although lateral jet action increases the effective width of the New York Slough diffuser, the parallel orientation is responsible for its lower initial plume dilution. A graphic representation of the parallel vs perpendicular orientation is shown by Figures 6-7 & 8.

Secondary dilution of the plume follows the process described above. Since secondary dilution is primarily time dependent, higher currents mean that the waste travels farther to achieve the same secondary dilution. However, since initial dilution is roughly proportional to current (above 0.4 kt for Browns Island and Shore Acres or 0.8 kt for New York Slough) the effects cancel such that the point of 100:1 dilution lies at a roughly constant position downstream. For Browns Island and Shore Acres this point is 1500 feet from the outfall; for New York Slough it is 4000 feet.

Effect of Ebb vs Flood Tide

The foregoing analysis presented the case of flood or incoming tide. The results from an ebb tide of similar peak current are essentially the same. The plume dilution is somewhat increased by the greater depth of the river available for discharge at high tide slack. The zone of impact may be derived from Figures 6-1, 2 & 3 by reversing the dispersion path shown, directing it down river along the flow line. Ebb tide cross-sections are shown in Figures 6-9 and 10. An ebb cross-section at Browns Island is not shown since river bottom topography there is essentially the same upstream and downstream.

AVERAGE CASE

Under average conditions, current is stronger, and the duration of slack is less. The waste discharge still forms a plume but the dimensions are smaller and dilution is somewhat better. Table 6-5 allows comparison.

Table 6-5

AVERAGE vs WORST CASE PALL

PARAMETER	NEW YORK SLOUGH	BROWNS ISLAND	SHORE ACRES
Time of Formation (min)	55 <u>15</u>	55 <u>15</u>	120 <u>35</u>
Pall at end of Slack			
Width (ft)	520 <u>300</u>	750 <u>450</u>	780 <u>575</u>
Length (ft)	950 <u>500</u>	720 <u>350</u>	980 <u>450</u>
Average Dilution	20:1 <u>41:1</u>	23:1 <u>48:1</u>	22:1 <u>45:1</u>
Time Required to Reach 100:1 (hrs)	4 <u>2</u>	4 <u>2</u>	4 <u>2</u>

Bold Face = Worst Case: Weak tide, Peak Discharge
ITALEC = ADVANTAGE CASE

The plume formed by current above the critical level is simply a function of current magnitude and varies continuously during the average tide as it does during the weak tide.

Figure 6-7 PARALLEL DIFFUSER ORIENTATION
(NEW YORK SLOUGH)

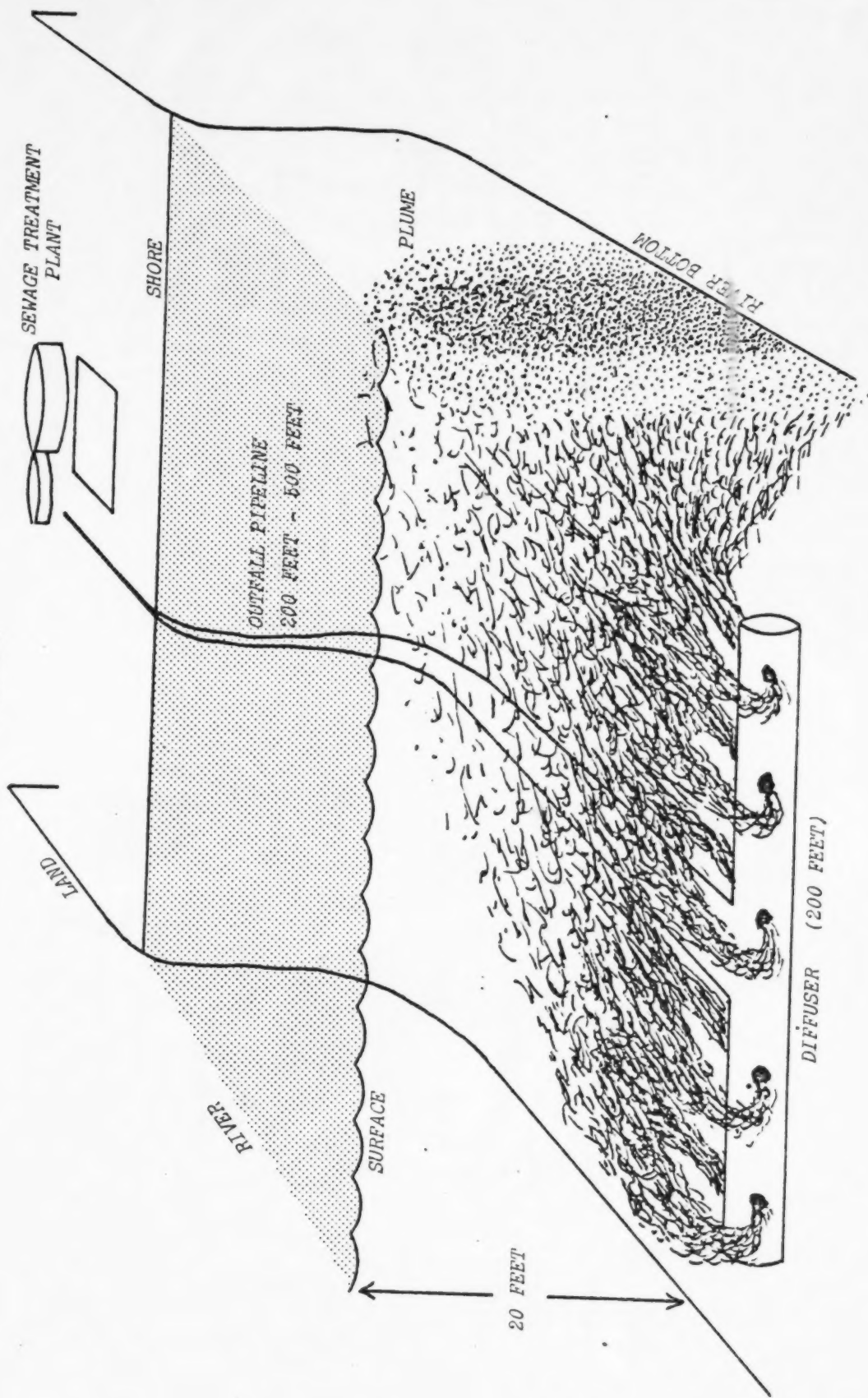


Figure 6-8 PERPENDICULAR DIFFUSER ORIENTATION
(SHORE ACRES AND BROWNS ISLAND)

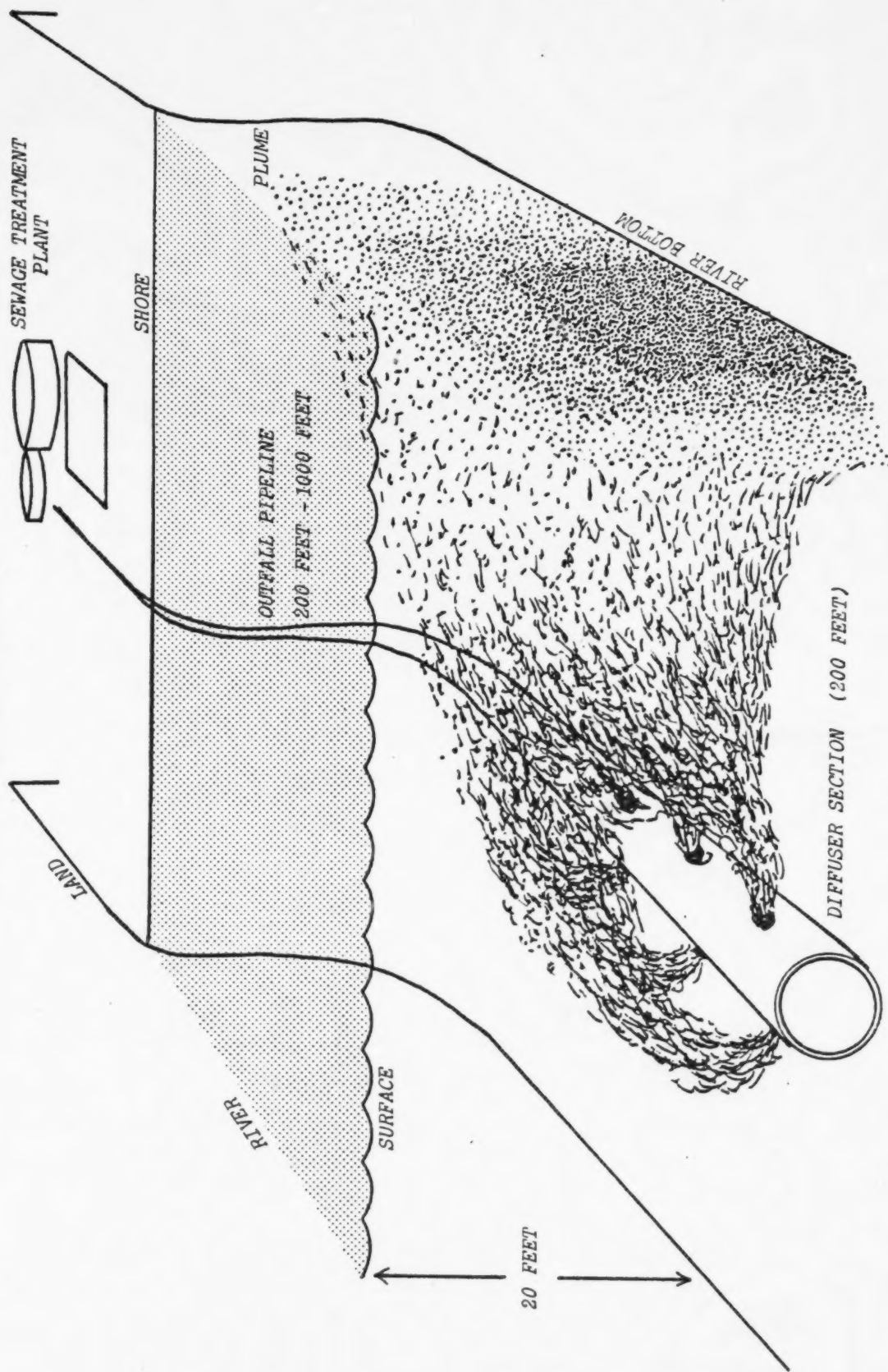


Figure 6-9 WORST CASE PALL MAXIMUM EXTENT
DOWNSTREAM—EBB TIDE
NEW YORK SLOUGH

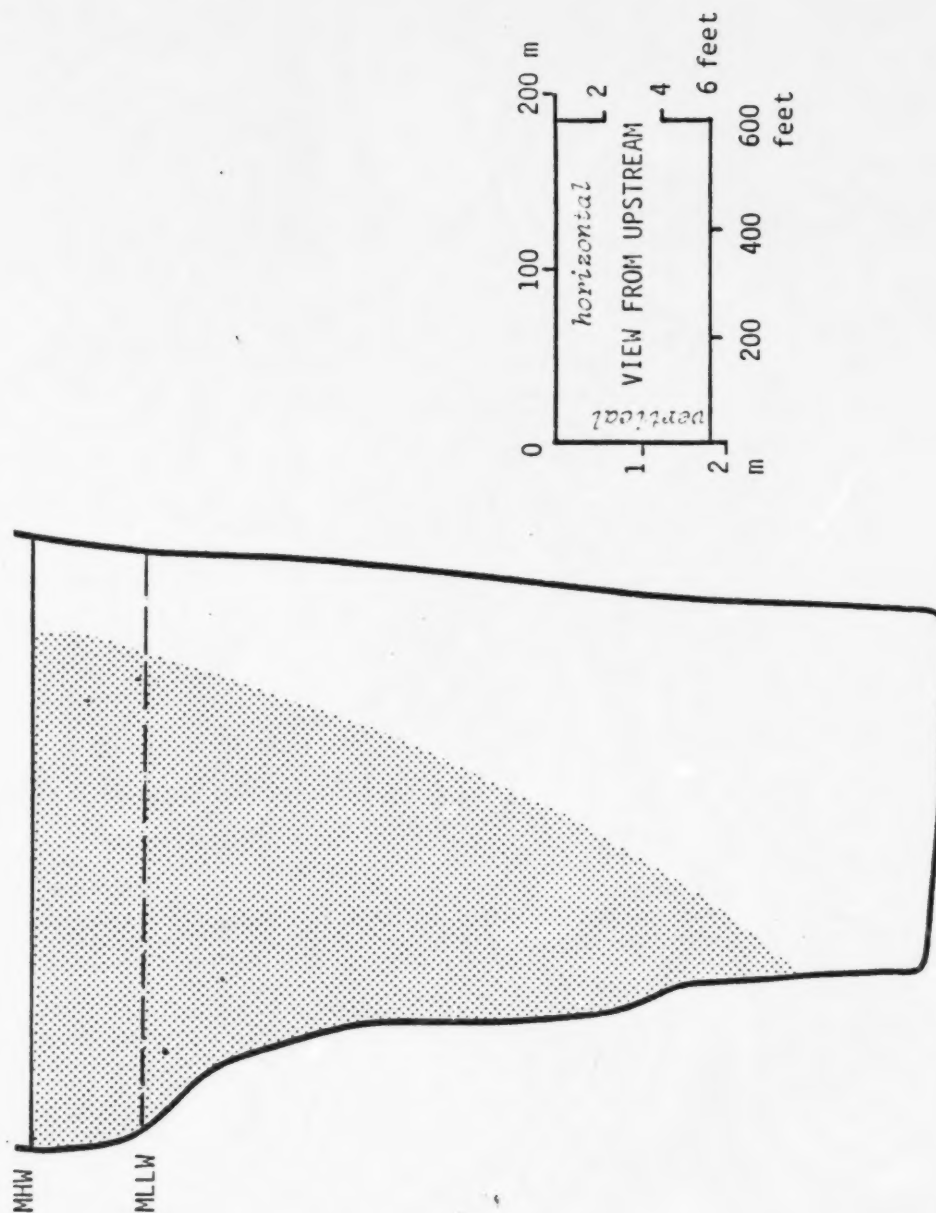
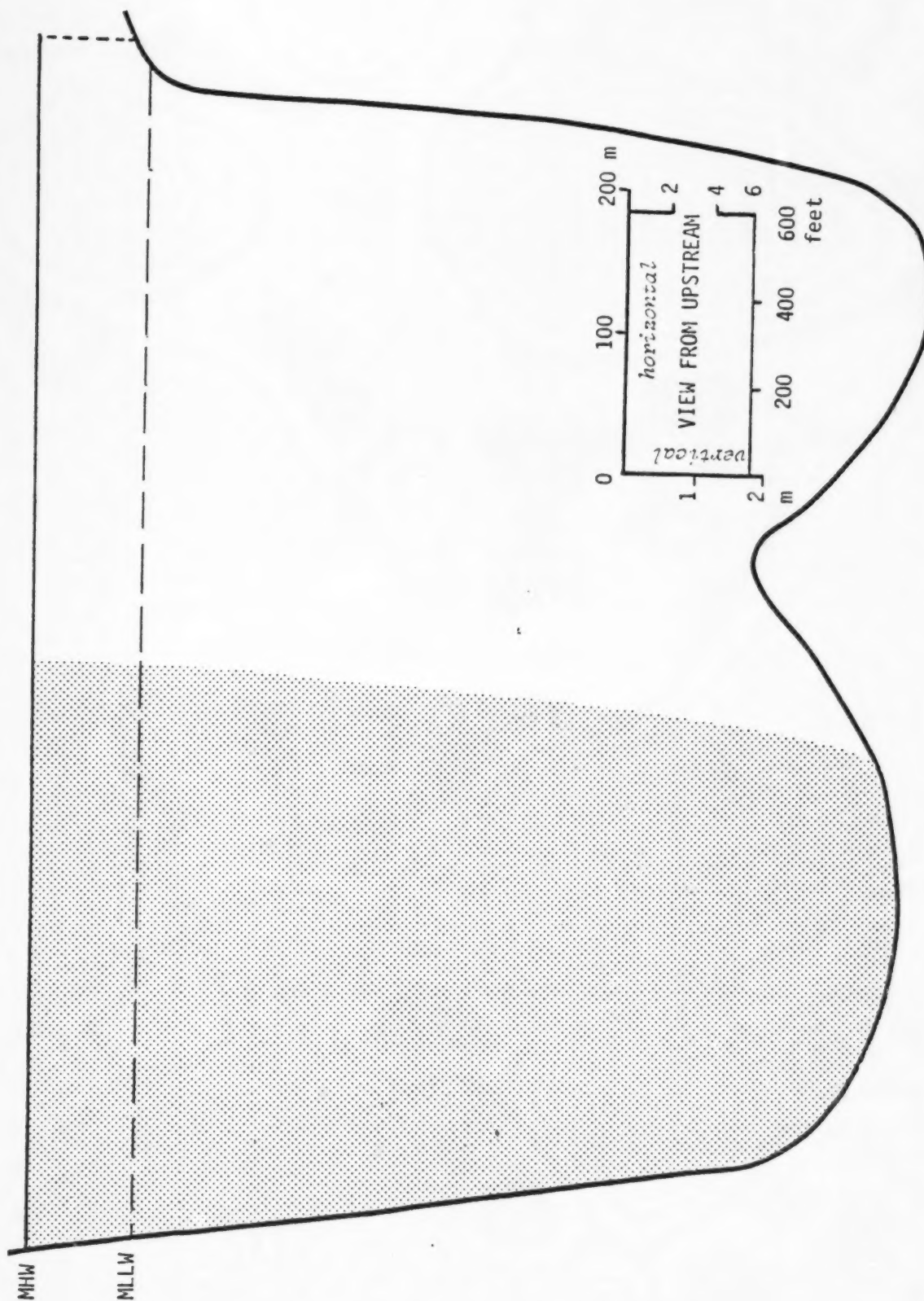


Figure 6-10 WORST CASE PALL — MAXIMUM EXTENT
DOWNSTREAM EBB TIDE
SHORE ACRES



EFFECT OF RIVER OUTFLOW

As noted above, tidal currents dominate the hydraulic environment of the study area. Since the phenomenon most adversely affecting discharge dilution is the duration of slack water, the effect of river outflow is not a major factor. Nonetheless, it is valuable to explicitly consider the problems of stratification during winter and of Delta withdrawals.

Winter

The majority of fresh water outflow occurs during late winter and early spring; the flow may reach 60,000 cfs -- ten times the dry season low. This outflow has three effects: 1) reduction in saline intrusion, 2) areas of salinity stratification, and 3) reduction in flood current.

Low salinity and stratification have a similar effect on discharge; both reduce the rise of the discharge jet. With a horizontal discharge jet, buoyancy is a major factor causing the waste to surface. During the winter the fall of wastewater may form along the river bottom, or slightly above. Dilution within the fall will be similar to the dilution estimated for summer conditions.

Overall, this discharge is not sensitive to variation in salinity. High velocity jets in 20 feet of water induce rapid dilution with a strong pumping effect that soon induces bottom to surface mixing in the absence of current. Secondary dilution factors do not rely on buoyancy spreading and hold for a submerged plume as well as for a surface plume. Both secondary dilution and initial dilution in moderate currents result in thorough vertical mixing within a few hundred feet.

Strong outflow during peak runoff may partially cancel the tidal current on incoming (Flood) tide.

This shifts the point of slack to a non-linear portion of the cycle, lengthening the interval for waste buildup. The effect is not as pronounced in the study area as it is for portions of the river near the city of Sacramento. The effect, if any, would be greatest at Browns Island and least at New York Slough.

Delta Withdrawal

Fresh water withdrawals on the Delta for agriculture and domestic supply result in severe diminution in Delta outflow and even reversal of net flow during certain months. Although this phenomenon reduces the Delta system flushing, it does not materially affect the local dilution of discharge at any location.

Similarly, the proposed peripheral canal would not adversely affect the immediate discharge dilution -- changes in gross flow and in salinity projected for that project will make little difference. Changes in other water quality parameters, particularly relating to Sacramento and Delta flushing, will effect the long-term retention of conservative pollutants, although the effect will be nearly equivalent for all three sites.

FINFISH SENSITIVITY TO WASTE DISCHARGE

General

The outfall/diffuser system described above is only a hydraulic mechanism for rapidly mixing and diluting the wastewater effluent. The actual impact of the discharge depends upon the pollutant load of the waste and upon the pollutant sensitivity of the receiving water biota. Together, these two factors, waste load and sensitivity, determine whether or not a certain degree of effluent dilution is acceptable.

The sensitivity of Study Area finfish to the four specific pollutants described is recapitulated by Table 6-6. The data are divided for very sensitive species such as trout and for more tolerant species such as perch or carp. Invertebrates, including the food source *Neomysis* are highly sensitive to some pollutants (chlorine), and should be placed in the trout/salmon category. Non-salmonid game fish, such as bass have intermediate sensitivity to most pollutants. The concentrations shown summarize the literature. They are conservatively chosen and generally represent concentrations which will probably not induce adverse effects over a period of two hours.

Exact values for sensitivity are difficult to obtain. The physiological action of all pollutants is dramatically affected by environmental and organismal factors such as temperature and salinity or reproductive status and nutritional condition. The values in Table 6-6 would probably be tolerated in the short-term as indicated, but could cause aversion or migratory interference and could over longer exposure cause direct toxicity.

The waste discharge is considered under worst and average case treatment plant functioning. The values for worst case usually assume total system failure with continuing discharge. The average effluent values reflect either the applicable NPDES discharge permit or the common value for secondary effluent.

Waste dilution results in diminished pollutant concentration. Table 6-7 sets forth the initial discharge concentration for worst and average case and shows the effect of dilution at 40:1 and at 100:1. Referring back to Table 6-6, it can be seen that only two waste components, chlorine and ammonia are problems with this degree of dilution.

Table 6-6
FISH TOLERANCE TO SHORT-TERM POLLUTANT EXPOSURE

POLLUTANT	CONCENTRATION (ppm) TOLERATED FOR FEW HOURS	
	<u>TROUT/SALMON</u>	<u>OTHER FISH</u>
1. Dissolved oxygen (DO)	7 ppm	5 ppm
DO depression* or BOD ₂ -hr	1	3
2. Ammonia (total)	0.5	1.0 - 2.0
3. Chlorine residual	0.002	0.01
4. Heavy Metals:		
Cadmium	0.03	0.03
Chromium (total or hexavalent)	1.0	1.0
Copper	0.02	0.02
Lead	0.1	0.1
Mercury	0.01	0.01
Zinc	0.1	0.1

* DO depression tolerances are based on fish DO tolerances of 7 and 5 ppm, and a summer background DO level of 8 ppm, as recorded in USBR water quality data.

Table 6-7 POLLUTANT CONCENTRATIONS RESULTING FROM DILUTION OF WORST CASE AND AVERAGE CASE WASTEWATER TREATMENT

(parts per million)

Pollutant	Dilution		Worst Case Discharge Total Plant Failure		Average Case Discharge Normal Operation	
	None	40:1	100:1	None	40:1	100:1
Chlorine residual	5	0.13	0.05	0.1	0.0025	0.001
Ammonia	30	0.75	0.3	20	0.5	0.2
BOD ₅ -day	200	5.0	2.0	30	0.75	0.3
BOD ₂ -hour	5	0.13	0.005	0.8	0.02	0.008
Heavy Metals:						
Cadmium	0.03	0.0008	0.0003	0.02	0.0005	0.0002
Chromium	0.01	0.0003	0.0001	0.005	0.0001	0.00005
Copper	0.3	0.0075	0.003	0.2	0.005	0.002
Lead	0.2	0.005	0.002	0.1	0.0025	0.001
Mercury	0.002	0.0001	0.00002	0.001	0.00003	0.00001
Zinc	0.5	0.0125	0.005	0.3	0.0075	0.003

Sensitive Fish Tolerance:

Borderline concentrations are underlined
Potential problems are circled.

Residual Chlorine

Residual chlorine can be abruptly toxic to fish, especially under some conditions (summer). Average effluent has to be dechlorinated with SO₂ to less than 0.1 ppm residual chlorine. At 40:1 dilution, that waste is present in borderline concentrations. Exposure

to less than 40:1 dilution for periods of more than roughly 2 hours may show adverse effects on sensitive species. Although dechlorination failure would be met by reduced chlorine feed rate and by detention, the possibility does remain that effluent would then contain as much as 5.0 ppm residual--50 times the expected average. Under those conditions the discharge would be toxic, requiring dilution of 250:1 to meet the short exposure criterion for sensitive fish.

Ammonia

Ammonia, a naturally occurring nitrogenous compound, is not proposed for treatment by the project. However, some reduction normally accompanies secondary treatment, and the discharge concentrations of worst and average cases are similar (Refer to Table 6-7). The waste diluted at 40:1 is at the tolerance borderline. Further dilution to 100:1 will be sufficient. The buffering capacity of the river is fairly high and changes in pH (acidity) will be minimal, even with dilution of only 5:1.

Dissolved Oxygen

Dissolved oxygen (DO) will not be significantly affected in the immediate waste plume. The secondary treatment is designed to reduce the oxygen demanding material within the waste (BOD), and average discharge diluted by only a few parts of receiving water would show only minor depression over 2 hours.

With plant failure, raw sewage discharge results in heavy BOD loading, but dilution of 5:1 would result in tolerable DO depression in the short term. The adverse effects of high BOD would be observed over several days with material trapped in poorly aerated, dead-end sloughs with the Delta. Over the short term the ammonia and chlorine toxicity effects would be more significant than BOD effects in the case of continuing discharge during catastrophic plant failure.

Heavy Metals

Heavy metals are not a major constituent of domestic waste. The metals most common, zinc, copper and lead, are the ones most likely to show short-term impacts. Among these, finfish are particularly sensitive to copper, and copper in project effluent requires dilution of roughly 10:1 to fall below the short-term tolerance level.

The values given by Table 6-6 are conservatively chosen. Background levels (See Table 4-1) often exceed the short-term tolerance to copper, and the impact should be seen as incremental or additive. A dense cloud of waste with less than 10:1 dilution could represent a detectably sharp concentration gradient to migrating fish and cause avoidance or raise the toxicity of background water within the cloud. Other metals do not appear to be involved in acute impacts.

CONCLUSION

Project Impact

Considering first the project as a whole, the foregoing analysis shows that the receiving waters of the Study Area generally provide a sufficient hydraulic environment for effective wastewater discharge dilution.

With normal plant operation, even worst case outfall conditions result in clearly tolerable concentrations (40:1 dilution) within less than two hours. Under average conditions, tolerable levels are achieved very quickly.

In the event of catastrophic treatment plant failure, unrestricted peak flow discharge under worst case conditions would result in high residual chlorine that could persist at unacceptable levels (less than 250:1 dilution) for as long as 8 hours. That event would cause mortality to sensitive species such as trout and *Neomysis*, and possibly to bass. Under average conditions, the exposure to unacceptable levels is reduced to roughly one hour or less; and the magnitude of potential fish kills would be less.

The alternative discharge sites do have slightly different hydraulic environments, and impact will vary between alternatives. The difference is small, however, and should be regarded only as an indication of alternative preference that may be weighed against other factors. In particular, the reader is cautioned that dilution calculations in a shallow tidal estuary are only approximate, and that the differences observed between the three alternatives is within the probable error of this method.

Among the three, New York Slough is least effective in diluting project effluent. Referring back to Tables 6-3 & 4, slightly smaller dilutions are obtained under both worst case and average current conditions. The principal factor that determines this result is the orientation of the diffuser parallel to current flow, due to the New York Slough ship channel. If the outfall were oriented perpendicular, the dilution at New York Slough would be nearly identical to the dilution at Browns Island.

Since the channel at New York Slough is narrower than at the other locations, there is greater potential for channel blockage. Under normal operation, no adverse effect is expected due to channel blockage. The general chlorine toxicity resulting from catastrophic plant failure would largely block the channel if it occurred during ebb tide. Although more sensitive species make primary use of just the Sacramento System, New York Slough is an important migrating route to the Delta for bass. The occurrence frequency of plant failure is small and not readily quantified. Conditions during which failure would be most damaging occur on the order of 10 hours per year (peak discharge, weak ebb tide, slack beginning).

The discharge at Browns Island will have slightly better dilution under all conditions than either alternative and lies in a broad channel less subject to blockage by the waste plume under conditions of plant failure. On flood tide, the pall of waste will probably be carried into the San Joaquin; on ebb, the pall will remain in the main channel of the Sacramento, and may interfere with important migratory routes.

Since Shore Acres discharges into a side channel, conditions result in longer periods of waste accumulation, and dilution is intermediate between the other two discharge alternatives. On flood tide, the side channel will be blocked under most conditions although this should not affect major fish movements.

In those instances where the waste accumulates and the pall contacts the shore at moderate dilution (100:1) it is important to consider shoreline sensitivity. All locations are bounded on one side by a wetland, with several drainage ditches that could admit pollutants on an incoming tide.

Possible Modifications and Mitigation

The project as presently proposed entails treatment at Camp Stoneman, between Pittsburg and Antioch, and discharge to New York Slough. This configuration was tentatively selected by the East/Central Agency as the apparent best alternative based on considerations of environmental impact and cost effective implementation of the wastewater program. Adoption of either discharge alternative would require substantial additional cost which the Agency must weigh against the purported environmental benefit.

With regard to acute, local water quality impact, the environmental benefit would be the slightly greater dilution at the alternative sites and the reduced impact of chlorine toxicity during plant malfunction. Since dilution is a function of outfall design as well as hydraulic environment, it is possible to devise modifications in design that can compensate for any differences. If the impact at New York Slough were considered undesirable as proposed, design modification may be as effective as outfall relocation in mitigation.

Two possible modifications would be effective:

- 1) Orient diffuser perpendicular to current, away from ship channel.
- 2) Provide substantial detention capacity to control discharge in relation to tidal stage or in the event of dechlorination failure.

At present, the parallel orientation of the New York Slough diffuser is the single major factor affecting relative dilution capacity at that location. It may be possible to change that orientation without interfering with ship channel use and maintenance dredging. Since the channel is deep close to shore and since the current profile is uniform across both breadth and depth, the outfall sewer leading to a "tee" section could be used as a diffuser itself resulting in a hybrid parallel/perpendicular diffuser. A variety of configurations could be applied. In addition, the simple expedient of increasing the length or increasing jet velocity can affect the initial dilution, as seen in Section 2.

Detention for treated effluent requires a large basin for storage and a series of pumps and controls. Typically, effluent is stored after chlorination, before dechlorination in order to allow partial dechlorination by aeration thereby reducing dechlorination chemical costs. This use (called "polishing") can provide valuable temporary storage in the event of dechlorination malfunction preventing discharge with high residual chlorine.

Secondly, detention allows control over discharge rates and may be used to vary discharge according to phases of the tidal cycle. For example, the occurrence of weak tides may be predicted in advance, and discharge could be restricted during the period of slack responsible for forming the pail of waste. Similarly, regional impacts of pollutant injection into the Delta may be markedly reduced by discharge during ebb tide. The degree of benefit is related to the sophistication and reliability of the control system.

The additional cost for these modifications is not trivial, yet is far less than the anticipated cost of re-locating the outfall site to Browns Island or to Shore Acres. The results of the acute impact analysis do not indicate whether or not the difference in dilution observed for New York Slough is unacceptable; that is a matter for the review and decision making process. Design modification becomes important only if it is determined that some mitigation is necessary and if a cost effective alternative to outfall relocation is sought.

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